Effects of Exercise Interventions on Stereotypic Behaviours in Children with Autism Spectrum Disorder

Christopher Petrus, Sarah R. Adamson, Laurie Block, Sarah J. Einarson, Maryam Sharifnejad, and Susan R. Harris

ABSTRACT

Purpose: The purpose of this systematic review was to synthesize evidence from studies examining the effect of exercise interventions on stereotypic behaviours in children with autism spectrum disorder (ASD).

Methods: Only exercise-related physical therapy (PT) interventions were included. A multifaceted search strategy identified studies published between 1980 and 2007. Quality was assessed using the American Academy of Cerebral Palsy and Developmental Medicine (AACPDM) Study Quality Scale, the Clinical Relevance Tool for Case Studies, and the Quality, Rigour or Evaluative Criteria tool.

Results: Seven studies (1982–2003) met our inclusion criteria; four of these used single-subject research designs, two were group studies, and one was a case study. Ages and behavioural characteristics of the children ($N = 25$) varied among the studies. Levels of evidence ranged from II to V (of a possible I–V). Study quality scores ranged from 2 to 5 (range: 0 to 7); mean = 3.9, mode = 5. Few studies in this area of PT practice have been published, and those identified scored low levels of rigour on the AACPDM criteria.

Conclusions: Research suggests that exercise provides short-term reductions of stereotypic behaviours in children with ASD. Future research with stronger evidence levels, greater rigour, and longer-term outcome assessment is required to determine specific exercise parameters.

Key Words: autism, autism spectrum disorder, exercise, stereotypical behaviours, systematic review

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RÉSUMÉ

Objectif : Cette étude méthodique a pour but de synthétiser les preuves scientifiques issues des études qui examinent l'effet des interventions par l'exercice sur les comportements stéréotypés chez les enfants atteints de troubles du spectre autiste (TSA).

Méthodes : Seules les interventions de physiothérapie liées à l'exercice ont été incluses. Une stratégie de recherche à facettes a identifié des études publiées entre 1980 et 2007. La qualité a été évaluée selon l'échelle de qualité des études étasuniennes *American Academy of Cerebral Palsy and Developmental Medicine (AACPDM) Study Quality Scale*, selon l'outil de pertinence clinique pour les études de cas (*Clinical Relevance Tool for Case Studies*) et selon l'outil des critères de qualité, de rigueur ou d'évaluation (*Quality, Rigour or Evaluative Criteria*).

Résultats : Sept études (1982–2003) ont satisfait à nos critères d'inclusion ; parmi celles-ci, quatre utilisaient des études de recherche individuelles, deux étaient des groupes d'études et la dernière était une étude de cas. Les âges et les caractéristiques de comportement des enfants ($N = 25$) variaient d'une étude à l'autre. Les niveaux de preuves scientifiques variaient de II à V (possibilité de I à V). Les scores de qualité des études variaient de 2 à 5 (gamme de 0 à 7); médiane = 3,9, mode = 5. Peu d'études dans ce domaine de la pratique de physiothérapie ont été publiées, et celles identifiées avaient des scores de rigueur de faibles niveaux selon les critères de l'AACPDM.

Conclusions : Les recherches suggèrent que l'exercice fournit à court terme des réductions de comportements stéréotypés chez les enfants atteints de TSA. Les recherches futures qui présentent des niveaux de preuves supérieurs, une plus grande rigueur et une évaluation à plus long terme sont requises pour déterminer les paramètres d'exercice spécifiques.

Mots clés: autisme, troubles du spectre autiste, exercice, comportements stéréotypés, étude méthodique

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BACKGROUND

Autism spectrum disorder (ASD) is a neurodevelopmental condition that is increasing in prevalence,[1] with four times as many males as females affected.[2] The current prevalence of ASD is now estimated to be more than 1 in 200 in Canada[3] and 1 in 150 in the United States.[4] The global prevalence of autism is also on the rise, with approximately 1 in 200 children being diagnosed with ASD.[3] Autism is now recognized as the most common neurological disorder affecting children and one of the most common developmental disabilities; ASD is more prevalent in the paediatric population than cancer, diabetes, spina bifida, or Down syndrome.[5]

Research is ongoing into the possible causes of ASD, such as genetics/heredity, differences in biologic brain function (neuropathology), prenatal factors, possible exposure to environmental toxins, viral infections, and immune deficiencies.[6,7] However, the features of ASD are generally agreed upon.

The category of ASD includes individuals specifically diagnosed with autism as well as those having the same core deficits to a lesser degree of severity,[8] such as children diagnosed with pervasive developmental disorder–not otherwise specified (PDD-NOS), Asperger syndrome,[9] childhood disintegrative disorder, and Rett syndrome.[9] The term "ASD" encompasses a variety of cognitive and neurobehavioural disorders with three salient features: impairments in socialization, impairments in verbal and nonverbal communication, and stereotypic and repetitive patterns of behaviours.[5,9] In the past, stereotypic behaviours have been variously labelled as stereotyped motor acts, ritualistic acts, and compulsive behaviours. Berkson and Davenport[10] inferred in 1962 that "stereotyped behaviours are self-stimulatory in character," and, as a result, both "stereotypic behaviours" and "self-stimulatory behaviours" are common terms, used interchangeably in the literature. Behaviours of this group are defined as responses that are stereotyped and repetitive, persist for long periods of time, and appear autonomous from social reinforcement. Common examples of self-stimulatory behaviours include rocking, spinning objects or self, and gazing at lights.[11]

Many children with autism display sensory and motor impairments in early development,[12] and, consequently, a range of interventions has evolved for use in treating these deficits. Baranek[12] conducted a literature review of these interventions: sensory integration therapy, sensory stimulation techniques, auditory and visual interventions, sensorimotor handling techniques, and physical exercise. The goal of these interventions is to target the features of ASD described above in order to facilitate the academic, leisure, and self-care skills of children with autism.

Baranek[12] noted that sensory or motor treatments are often used to complement a more holistic intervention plan. For example, the occupational therapist or PT provides therapeutic interventions aimed at improving a child's performance. Remediation of sensory or motor deficits (as well as other components, including cognitive or psychosocial functions) may take place, if indicated, but only within the larger context of occupational performance problems within the learning environment. Compensatory interventions and environmental adaptations are also used, and these are often preferred because of their more immediate effects on meaningful participation.

The benefits of exercise in typical populations have been well documented in the literature.[13] Exercise programmes have also been used as interventions for a variety of developmental and psychiatric disorders,[14] with overall positive effects on reducing atypical behaviours. A similar result was shown for adults with autism (and mental retardation) benefiting from exercise.[15] However, few articles to date have examined the effectiveness of PT interventions, specifically exercise, on the stereotypic behaviours of autism in children.

Although physical exercise is included in many regular education curricula, it is not systematically or consistently used in children with autism.[12] There is speculation that aerobic exercise physiologically modulates stereotypic behaviours of autism through the release of specific neurotransmitters,[12] and such speculation has generated interest in the application of physical exercise as an intervention for stereotypic behaviours of autism. Others have suggested that increased amounts of physical exertion and the resulting fatigue lead to decreases in inappropriate behaviour[16] (e.g., stereotypical behaviours).

For this systematic review, exercise interventions, defined as exercise or physical activity or physical education (such as occurs in school settings), were the independent variables. The dependent variable, the frequency of stereotypic behaviours, was defined by each of the study authors. The outcome of interest was reduction of stereotypic behaviours (either short- or long-term). Although this is an impairment-level outcome, it is plausible that a decrease in stereotypic behaviours might contribute to greater participation and skill development, in the classroom or at home. The population of interest was children under 19 years of age, with a diagnosis of autism or ASD. No review on this topic has been published, and no in-progress review is registered in the Ongoing Reviews Database of the Centre for Reviews and Dissemination.

The purpose of this systematic review was to assess the current literature with respect to the effectiveness of exercise interventions on reducing stereotypic behaviours in children with autism. The results can then be used by PTs working with children with autism.

Limitations in the compiled studies, as well as recommendations and directions for future research, are also described below.

METHODS

Data Sources

A comprehensive search strategy was used to locate the most recent literature relating to the subject. The strategy included searching electronic databases, manually searching reference lists, and communicating with experts in the fields of both paediatric PT and autism.

The following electronic databases were searched from September 2005 to April 2007: MEDLINE, EMBASE, PsycINFO, PEDro, ERIC, Cochrane Database of Systematic Reviews, Cochrane Controlled Trials Register, and CINAHL. Search terms used were "autism," "autism spectrum disorder," "exercise," "physical activity," and "physical education." Expanded MESH terms related to these key words were used when appropriate. In addition, the Web of Science database was used to search the names of the authors who had written the seven articles used in this systematic review. This database was used also to perform journal searches of the *Journal of Autism and Developmental Disorders*, *Pediatric Physical Therapy*, *Physical and Occupational Therapy in Pediatrics*, *Developmental Medicine and Child Neurology*, and *European Academy of Childhood Disability*.

Scientific grey literature was searched in order to identify information not readily available through the above databases. Initially First Search/Papers First was searched; this is an index of papers that includes those presented at worldwide conferences. This search found 1,003 articles on autism; however, none of them explored physical activity as an intervention. Next, the reference lists of the first six relevant studies found through our main database search were manually searched, yielding another relevant article by Kern et al.[17] Finally, key individuals were contacted for assistance in finding relevant studies. No additional exercise intervention studies were found involving children with autism.

Study Selection

Searches were limited to studies done in English using human subjects. Titles were screened initially, and papers were excluded if they were exclusively related to medications, genetics, cognition, memory, communication, or executive functioning. Abstracts were independently reviewed by two authors to further refine the search, and the following inclusion criteria were implemented: (1) intervention study using either exercise or physical activity as the independent variable, (2) frequency of stereotypic behaviours as the dependent variable, (3) children under 19 years of age, (4) subjects stated to have autism or ASD. Entire studies were reviewed independently by two authors, using the same criteria for inclusion as were used for the abstracts. Any differences between reviewers during these stages were resolved through discussion.

Data Extraction

The American Academy of Cerebral Palsy and Developmental Medicine's (AACPDM) Levels of Evidence was used for this systematic review (see Table 1),[18] as well as an adapted version of their data extraction form that included the following: (1) analysis of evidence level; (2) quality of the study; (3) descriptive information about the study, including population description and specific interventions used; and (4) outcome of interest. For studies that used single-subject research designs, a preliminary version of the Levels of Evidence for Single Subject Research Designs tool was used (see Table 2).[19]

Study Quality Assessment

Three scales were used for the analysis of study quality, based on the type of study design used: (1) the AACPDM Study Quality Scale;[18] (2) the Clinical Relevance Tool for Case Studies,[20] modified from van

Table 1 American Academy of Cerebral Palsy and Developmental Medicine Levels of Evidence[19]

Level	*Study Design*
I	Systematic review of randomized controlled trials (RCT)
	Large RCT (with narrow confidence interval)
II	Smaller RCTs (with wider confidence intervals)
	Systematic reviews of cohort studies
	"Outcomes research" (very large ecologic studies)
III	Cohort studies (must have concurrent control group)
	Systematic reviews of case-control studies
IV	Case series
	Cohort study without concurrent control group (e.g., with historical control group)
	Case-control study
V	Expert opinion
	Case study or report
	Bench research
	Expert opinion based on theory or physiologic research
	Common sense/anecdotes

Table 2 Harris Levels of Evidence for Single Subject Research Designs[19]

Level	*Study Design*
I	N-of-1 RCT
II	ABABA design
	Alternating treatments design
	Multiple baseline (concurrent or non-concurrent; across subjects, settings, or behaviours)
III	ABA design
IV	AB design (with replication on ≥ 1 subject)
V	AB design (with 1 subject)

RCT = randomized controlled trial

Tulder et al.[21] by students in the Master of Physical Therapy programme at the University of British Columbia (see Table 3); and (3) the Quality, Rigour or Evaluative Criteria, adapted from Horner et al.[22] by this article's last author[19] (see Appendix). Modifications were made to the study quality assessment for case-study designs, as some of the questions posed in the original version (e.g., number of dropouts) were not applicable.

Study Quality Scale

All three scales use similar seven-point criteria, facilitating comparisons across the seven studies. Scores on all scales were interpreted as strong (6 or 7), moderate (5), or weak (< 4). The seven criteria for judging the quality of each study are presented in Table 3.

Two reviewers independently assessed study quality for each study. Any disagreements were discussed between the two reviewers, and a final decision on the quality score was attained through consensus.

Table 3 Clinical Relevance Tool for Case Studies (modified from van Tulder et al.[21])

Description		
A.	Was the purpose of the study clearly stated?	Yes/No/Not Sure
B.	Was the hypothesis clearly stated?	Yes/No/Not Sure
C.	Were the patients described in detail so that you could decide whether they are comparable to those seen in practice?	Yes/No/Not Sure
D.	Were the interventions and treatment setting described well enough so that they could be replicated?	Yes/No/Not Sure
E.	Were the measures used clearly described, valid and reliable for measuring the outcome of interest?	Yes/No/Not Sure
F.	Was the size of the effect clinically important?	Yes/No/Not Sure
G.	Were the limitations of the study identified & discussed?	Yes/No/Not Sure
TOTAL /7		

Data Synthesis

The studies included in this systematic review were classified into three tables (Tables 4, 5, and 6) to clearly depict study quality and design type, sample characteristics, intervention type, outcome of interest, and results.

RESULTS

The electronic literature search identified 200 articles; this list was narrowed down to 42 titles, including possible duplication of titles/studies between database searches. Of these, 29 were excluded, leaving 13 abstracts. Based on further review, 6 more studies were eliminated, leaving 7 articles that fit the inclusion criteria (see Figure 1).

Of the seven articles identified, four used single-subject research designs, two used group designs, and one was a case study. Children were of both genders, with an age range from 4 to 15 years. Across all 7 studies, 26 children with ASD were included. Participants were stated to have autism or ASD, as diagnosed by one or more clinicians. Many of the participants were stated to have high levels of stereotypic behaviour. All of the studies had an exercise intervention with a measure of frequency of stereotypic behaviour as the dependent variable (see Table 5). Baseline measurements of

Table 4 Study-Quality Assessment Using Criteria from O'Donnell et al.,[18] Harris,[19] and van Tulder et al.[21]

A *Study Quality – Single Subject Research Designs (adapted from Harris[19])*

First Author (Year)	*Operational Definitions*	*Independent Variable Defined and Manipulated*	*Dependent Variable Defined and Measured (minimum of 3 times)*	*Blinding*	*Appropriate Statistics*	*Dropouts*	*Control of Bias / Confounding Variables*	*Total*
Bumin (2003)[23]		√				√		2
Celeberti (1997)[24]	√		√		√			3
Kern (1982)[17]	√		√	√				3
Kern (1984)[28]	√	√	√	√		√		5

B *Study Quality – Case Studies (adapted from van Tulder et al.[21])*

First Author (Year)	*Purpose Stated*	*Hypothesis Stated*	*Patients Described*	*Intervention and Treatment Described*	*Measures Described*	*Effect Size*	*Limitations Identified*	*Total*
Levinson (1993)[25]			√	√		√		3

C *Study Quality – Group Design (adapted from O'Donnell et al.[18])*

First Author (Year)	*Inclusion/Exclusion Criteria*	*Adherence*	*Measure*	*Blinding*	*Appropriate Statistics*	*Dropouts*	*Control of Bias*	*Total*
Watters (1980)[26]	√	√	√		√	√		5
Rosenthal-Malek (1997)[27]	√		√		√	√	√	5

Table 5 Summary of Studies – Interventions and Participants

First Author (Year)	*Group Design (Evidence Level)*	*Intervention*	*Control Intervention*	*Sample*	*Severity*	*N*	*Age (years)*
Bumin (2003)[23]	AB (Level V)	• Halliwick method of hydrotherapy: adjustment to water, rotation, control of movement in water • 2 sessions per week for 8 weeks • 1:1 PT:child treatment ratio	None	Rett syndrome ($n=1$ female)	Stage III Rett syndrome	1	11
Celeberti (1997)[24]	AB, one subject only (Level V)	• Two levels of exercise: 6 min walking vs. 6 min jogging	None	Autism	Mild to moderate with high rates of "stereotypical" and "non-compliant" behaviour	1	5
Kern (1982)[17]	ABABA (Level II)	• Jogging (mildly strenuous), 5–10 min initially, 20 min by end of study	None	Autism	Particularly high levels of self-stimulatory behaviour	4 3	4–7.5 9–14
Kern (1984)[28]	Alternating treatments design (Level II)	• Ball playing 15 min, throwing 2–3 min 10–20×/min • Jogging for 15 min with 15-second walk/rest as required	None	Autism	Particularly high levels of self-stimulatory behaviour Social Quotients (Vineland Social Maturity Scale): 80, 60, 22	3	7, 11, 11
Levinson (1993)[25]	Case study (Level V)	• 15 min each of walking or jogging	None	Autism and stereotypic behaviours (2 male, 1 female)	Low-functioning, pre-adolescent	3	11
Rosenthal-Malek (1997)[27]	One-group, repeated measures (Level IV)	• Aerobic exercise: warm-up stretches and mildly strenuous jogging (20 min) • Academic precondition: academic subjects taught, following standard classroom procedures	None	Autism, male	Not stated	5	14–15
Watters (1980)[26]	Pretest–posttest, case series (Level IV)	1–4 of the following activities were performed each week, no more than 1 session/day, for 27 total sessions: • Jogging for 8–10 min (11 sessions) • Academic group activities and intensive one-on-one academic training, typical school day (11 sessions)	10–15 minutes watching TV (*Sesame Street*); teachers ensured children remained in their seats (5 sessions)	Autism, male, self-stimulatory behaviours present	Non-vocal, self-stimulatory behaviours were displayed, if not controlled by the teacher	5	9–11

Table 6 Summary of Studies – Outcomes, Measures, and Results

First Author (Year)	*Evidence Level (Study Quality)*	*Outcome of Interest*	*Measure*	*Results*
Bumin (2003)[23]	Level V (2)	Stereotypical movements	Hand-to-mouth	Decreased
			Hand squeezing	Decreased
			Hand wringing	No decrease
		Functional hand use	Drinking, picking up and eating cracker placed on table	Improved
		Hand skills	Grasping and holding objects for 10 sec Transferring small and large objects from one point to another	Improved
		Gait and balance	Gait apraxia	Improved
			Trunk ataxia	Improved
			Poor balance	Improved
Celeberti (1997)[24]	Level IV (4)	Self-stimulatory behaviour after jogging and walking	Any instance of physical self-stimulation, defined as non-functional movement of the arms, hands, or fingers (e.g., waving, banging or hitting) during a 10-sec period; or visual self-stimulation (squinting or peripheral staring) for at least 2 sec during a 10-sec period	*Physical Stimulation* Baseline mean = 59% Post-jogging mean = 41% Post-walking mean = 61% *Visual Stimulation* Baseline mean = 65% Post-jogging mean = 57% Post-walking mean = 63%
		Out-of-seat behaviour in an academic setting after jogging and walking	Any instance where child's buttocks were not in contact with his chair for >2 seconds or when the child jumped up and down	*Out-of-Seat Behaviour* Baseline mean = 19 episodes Post-jogging mean = 9 episodes Post-walking mean = 14 episodes
		Temporal effects of exercise	Measurement of the above during 10-min blocks of time over a 40-min period	*Post-Jogging* Physical self-stimulatory behaviours and out-of-seat behaviours remained below baseline levels for the 40-min measurement sessions.
Kern (1982)[17]	Level II (3)	1. Self stimulation	1. Time-sampling procedure (5-min sample period data recorded during 5-sec intervals)	1. Marked decrease in self-stimulatory behaviour post-jogging within and across days
		2. Ball playing	2. Maximum rate of ball-playing (ball thrown at minimum rate of 5 times per min)	2. Ball playing increased.
		3. Academic responding	3. Child's response on each trial was recorded as correct if the child responded appropriately to the discriminative stimulus.	3. Academic responding increased.
Kern (1984)[28]	Level II (5)	Stereotypic behaviours	Observation for six 15-min blocks with data recording for the first 5 min of each block Time-sampling procedure: 15-sec intervals (5-sec observation, 10-sec data recording); absence (−) or presence (+) of stereotypic responding recorded on pre-coded data sheets	*Jogging*: Decrease in stereotypic behaviours after jogging sessions for all participants *Ball Playing*: No systematic changes after ball-playing sessions

(Continued)

Table 6 Contd.

First Author (Year)	*Evidence Level (Study Quality)*	*Outcome of Interest*	*Measure*	*Results*
Levinson (1993)[25]	Level V (3)	Frequency of self-stimulatory behaviours (motor, vocal/oral, other) immediately following exercise and 90 min post-treatment	The proportion of recording intervals in which a given subject engaged in stereotypic behaviour patterns—an interval sampling procedure was used Heart rate and distance covered were measured to bring more stringent differentiation between the two exercise treatments.	*Walking:* not associated with decreases in stereotypic behaviours *Jogging:* resulted in a reduction of stereotypic behaviour *90 min Post-Walking:* continued to demonstrate pretreatment levels of stereotypic behaviour *90 min Post-Jogging:* subjects returned to or exceeded pretreatment levels of stereotypic behaviours
Rosenthal-Malek (1997)[27]	Level IV (5)	1. Amount of stereotypic behavior	1. Two observers independently observed children for stereotypic behaviors	Aerobic exercise resulted in significantly improved outcomes as compared to the academic precondition
		2. Level of correct academic responding	2. Total number of correct academic responses was counted	Aerobic exercise resulted in significantly improved outcomes as compared to the academic precondition
		3. Amount of work completed in the community workshop	3. Total number of jobs completed was counted in the workshop	Aerobic exercise resulted in significantly improved outcomes as compared to the academic precondition
Watters (1980)[26]	Level V (5)	Self-stimulatory behavior and academic performance following a period of physical activity OR academic activity OR television watching	Self-stimulatory behaviors and academic performance were monitored during 27 language-training sessions, designed to follow the three interventions randomly. Monitoring of self-stimulatory behaviours consisted of an observer using a 5-sec observe / 5-sec record sampling scheme; a second observer participated in 19 of the 27 sessions. Monitoring of academic performance was done by counting the number of correct answer choices in the auditory–visual matching task that constituted the language training; two teachers recorded correct answers.	*Self-Stimulatory Behaviour:* Decreased post–physical exercise as compared to post–academic activity *Academic Performance:* The levels of correct answering were not different following physical exercise or academics. No differences were found between outcome levels following TV watching; this indicates that a change in routine was not the reason behind the decrease in self-stimulatory behaviors.

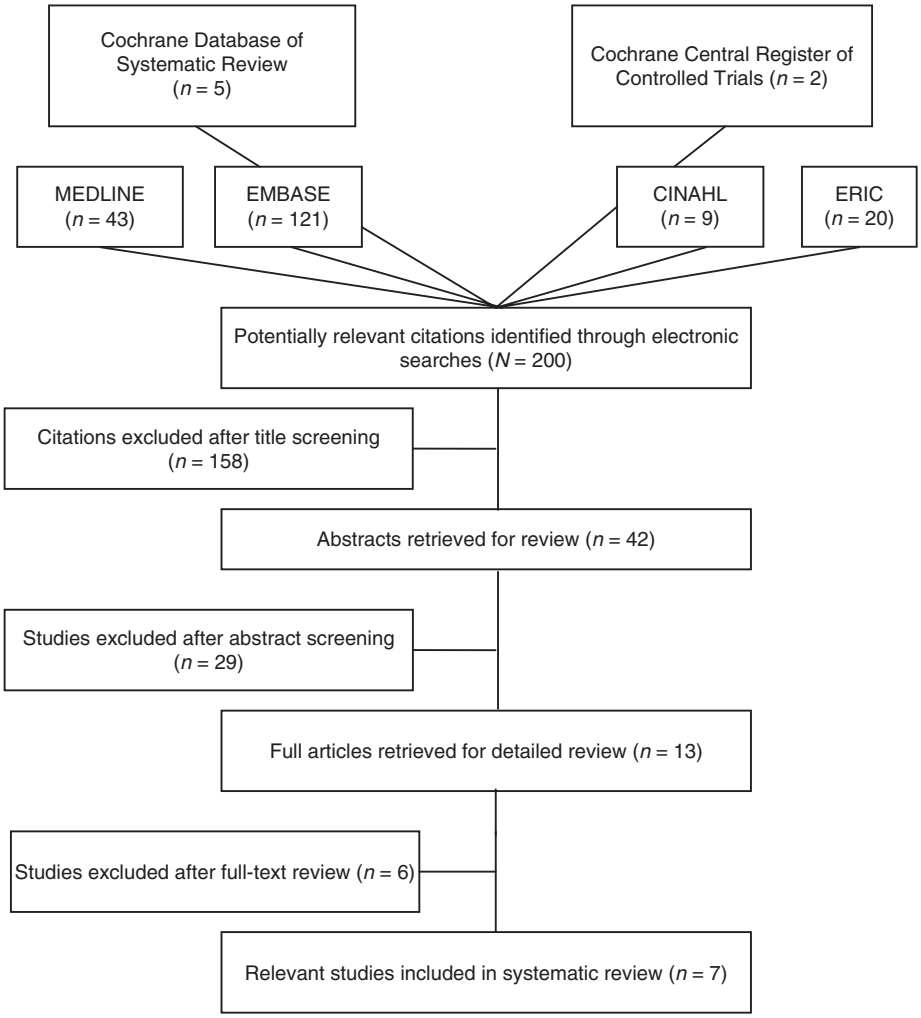

Figure 1 Flow diagram of study selection.

behaviours for each subject were observed. These behaviours often varied among subjects, and individualized baselines were therefore employed. One or more researchers observed the subject after exercise and compared this measurement to the individual's baseline.

The levels of evidence ranged from II to V: 2 studies contributed Level II evidence, 2 contributed Level IV evidence, and 3 contributed Level V evidence. The study quality scores ranged from 2 to 5, with a mean of 3.9 and mode of 5. The quality of the 7 articles included in this review was assessed as follows: 2 studies were critiqued using the AACPDM criteria,[18] 4 using the Harris criteria,[19] and 1 using the MPT student criteria.[20] When results of the 3 study-quality scales were compared, 3 articles (42%) received moderate scores, and the remaining 4 articles (58%) were rated as weak (see Table 4).

Six of the studies used jogging as the exercise intervention; the remaining study used hydrotherapy (see Table 5). Post-exercise self-stimulatory behaviours were measured using time-sampling techniques in all studies except that of Bumin et al.,[23] who did not include this methodological detail. Time sampling measures the occurrence or non-occurrence of a behaviour or event at specific points over an observation period (e.g., once every 30 seconds).[24] A decrease in self-stimulatory behaviour following the exercise intervention was noted in all of the studies. Three of the studies documented the post-exercise effect over varying lengths of time. Celeberti et al.[25] found that self-stimulatory behaviours remained below baseline for the entire 40-minute observation period following exercise. Kern et al.[17] found marked decrease in self-stimulatory behaviours post-jogging within and across a period of 2 days. However, Levinson et al.[26] stated that 90 minutes post-jogging, participants had returned to or exceeded pretreatment levels of stereotypic behaviours; thus, the post-exercise effect was not maintained over the long term (see Table 6).

DISCUSSION

Exercise is an intervention within the scope of PT practice; however, its role has not been rigorously

examined with regard to treatment of children with ASD. Given that exercise and exercise prescription are integral components of PT practice, it is important that clinicians be aware of existing research findings in order to make appropriate and informed treatment recommendations.

All seven studies examined the effect of short intervals of exercise on stereotypic behaviours, as defined in the individual studies. The mode of exercise varied among the studies, and six of the seven articles also examined other outcomes following exercise, such as academic responding and performance of play tasks.

Three studies examined the effect of exercise on stereotypic behaviours and academic performance.[17,27,28] In a Level IV study, Watters and Watters[27] examined the effects of 8–10 minutes of jogging, 10–15 minutes of television watching, and varied academic classroom activities on stereotypic behaviours and academic performance. No changes in academic performance were reported following any of these interventions, and stereotypic behaviours decreased only after exercise, suggesting that the exercise intervention alone reduced the frequency of stereotypical behaviours of the study group. In another Level IV study, Rosenthal-Malek and Mitchell[28] report that 20 minutes of jogging, compared to an academic precondition of classroom activity, was associated with a decrease in stereotypic behaviours, an increase in on-task behaviour (defined as jobs completed in a workshop), and an increase in academic performance. Exercise was found to decrease stereotypic behaviours in these two studies, but this finding would be strengthened by more rigorous study designs. Both studies were given a score of 5 based on quality and were therefore rated as providing moderate evidence that exercise reduces stereotypic behaviours. In a Level II study, Kern et al.[17] investigated the effects of 5–20 minutes of jogging on stereotypic behaviours, academic tasks, and catching tasks. All three outcomes improved post-exercise, with consistent decreases in stereotypic behaviours and improvements in both academic and catching tasks observed post-jogging. This study's quality was rated as 3, and thus it provides weak evidence to support this result.

A Level V study by Bumin et al.[23] involved a single subject with Rett syndrome, a neurodevelopmental disability encompassed by the ASD designation. The authors of this study employed the Halliwick method of hydrotherapy and measured its effects on stereotypic movements (hand-to-mouth, hand squeezing, and hand wringing) as well as on other outcomes such as feeding, functional hand use, hand skills, gait, and balance. Improvements in all outcome measures were observed (except for hand wringing) 5 minutes after each hydrotherapy session over the course of 8 weeks. As this study's quality was rated 2, only weak support can be inferred for the benefits of hydrotherapy on stereotypic behaviours of children with Rett syndrome. Because this was the only study to use hydrotherapy as a form of physical activity, a stronger study design is required to reinforce the reported benefits.

Three studies further explored the relationship between exercise and stereotypic behaviours by varying the intensity of exercise. In the Level II study by Kern et al.,[29] exercise was carried out in 15-minute intervals of "vigorous" or "mild" intensity, defined by the authors as jogging or ball playing, respectively. A decrease in stereotypic behaviours was recorded after jogging, but not after ball playing. This study was rated 5 for quality and thus provides moderate evidence. The Level V study by Celiberti et al.[25] also examined the effects of low- versus high-intensity exercise on stereotypic and out-of-seat behaviours by using 6 minutes of jogging versus 6 minutes of walking. The results indicate that jogging reduced stereotypic and out-of-seat behaviours, whereas walking did not produce any decrease in these behaviours. It was noted that stereotypic and out-of-seat behaviours remained below baseline for the duration of the 40-minute measurement sessions. The Level V study by Levinson and Reid[26] also used the treatment conditions of walking and jogging to vary exercise intensity. This study was more objective in its measurement of intensity, as it used pre- and post-exercise heart rates and distance covered over 15 minutes. Levinson and Reid found that walking was not associated with decreases in stereotypic behaviours either immediately following exercise or 90 minutes later. Jogging resulted in a reduction of stereotypic behaviours immediately following exercise, but the participants returned to or exceeded pretreatment levels of stereotypic behaviours by 90 minutes post-jogging. These three studies provide moderate[29] and weak[25,26] support for the idea that vigorous exercise produces short-term decreases in stereotypic behaviours, whereas mild exercise has little influence. These findings further support the premise that exercise decreases self-stimulatory behaviour, although long-term benefits have not been examined.

The lack of recent publications in this area indicates a need for further research and stronger evidence to support the effect of exercise on stereotypic behaviours. The publication dates of the 7 articles ranged from 1980 to 2003, covering a 23-year span. Because of the limited body of research in this area, no exclusion criteria were created with respect to the publication date of articles to be included. This further illustrates the need for more rigorous research in this area to determine the concrete effects of exercise on stereotypic behaviours in children with autism.

Taken together, the articles in this review provide weak to moderately strong evidence that exercise decreases stereotypic behaviours. Two Level II studies suggest an effect, and both these studies indicate that higher-intensity exercise was more effective in decreasing self-stimulation. Results of two Level IV and three

Level V studies also suggest decreases in self-stimulation following exercise. All studies reported beneficial and temporary effects of exercise in decreasing stereotypic behaviours. Effects were greater with more intensive aerobic activity. However, the heterogeneity of the research designs and interventions makes it difficult to determine appropriate prescription of exercise for children with ASD. Different forms of exercise (e.g., jogging, hydrotherapy) and varying measures of exertion and intensity (e.g., flushed face, heart rate, appearance, no monitoring) further complicate the process of making precise recommendations regarding exercise prescription to reduce stereotypical behaviours in children with ASD. The heterogeneity of the study designs, the small numbers of participants, and the absence of any randomized controlled trials among the studies included made it impossible for us to conduct a quantitative analysis (i.e., meta-analysis) of the results across the seven studies.

Additional research using stronger designs (e.g., randomized controlled trials), with improved quality and greater numbers of participants, is required to determine prescription of appropriate PT intervention for children with ASD. For example, as Elliott et al.[15] noted in a study of exercise in a sample of adults with autism, few studies are specific in describing the parameters of aerobic exercise. As Lochbaum and Crews[30] noted, the actual type (e.g., acute vs. chronic), intensity (e.g., low, moderate, heavy), and duration (e.g., minutes/session, weekly) of exercise required are still unclear. Moreover, the duration of positive effects post-exercise has been reported as temporary.

Despite these limitations, the literature does suggest that exercise has a beneficial, albeit short-term, impact in reducing stereotypical behaviours in children with ASD. Furthermore, benefits were not limited to these behaviours; several studies in this review found improvements in other areas (e.g., academic responses, on-task behaviours).[17,23,25,29]

Additional limitations of this systematic review are based on the following factors. Articles included were limited to English-language publications, which may not have allowed for a complete perspective of current possible evidence. Only published articles were included, which may have subjected the review to publication bias. Finally, we failed to analyze percentage agreement for the study-quality ratings but discussed any disagreements until consensus was reached.

CONCLUSION

The purpose of this systematic review was to assess the current literature with respect to the effects of exercise on stereotypic behaviours in children with ASD. Although the evidence is weak to moderately strong, the literature does suggest that exercise produces short-term decreases in stereotypic behaviours in this population. There is also supporting evidence that higher-intensity exercise is more effective than lower-intensity activity in decreasing self-stimulation. Physiotherapists working in paediatric practice should consider the above points when working with children with autism displaying stereotypic behaviours. Although the heterogeneity of the research designs and interventions makes it difficult to determine specific prescription of exercise for children with ASD, the studies reviewed included various types and intensities of exercise that are clinically relevant for physiotherapists working with children with ASD who have different capabilities and tolerance levels for certain activities. Further research using more rigorous methods with greater numbers of participants is needed to determine specific exercise prescriptions within PT treatment for children with ASD.

KEY MESSAGES

What Is Already Known on This Subject

Little is known about effective interventions to reduce stereotypical behaviours in children with autism spectrum disorders (ASD), the most common neurological disorder affecting children, and yet these behaviours often interfere with these children's meaningful participation in school and home activities. Exercise (physical activity) has been postulated to be an intervention that can reduce stereotypical behaviours, but no systematic review of this intervention literature has been published.

What This Study Adds

This systematic review summarizes the seven available studies (1982–2003) examining the effects of exercise interventions on stereotypical behaviours in children with ASD. Although the quality and rigour of the evidence are only weak to moderately strong, a systematic synthesis of the research suggests that exercise produces short-term decreases in stereotypic behaviours in this population. Paediatric physiotherapists who work with children with ASD should consider including exercise as an intervention when treating children with autism who display stereotypic behaviours.

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APPENDIX: QUALITY, RIGOUR OR EVALUATIVE CRITERIA

1. Were operational definitions provided for the participant, setting and process by which participants were selected?
2. Was the independent variable operational defined, systematically manipulated, and fidelity of its implementation ensured?
3. Were dependent variables operationally defined, measured repeatedly (a minimum of three data points) during each phase of the design, and assessed for inter-observer reliability during each phase?

4. Was the outcome assessor unaware of the intervention status/phase of the participants(s)?
5. Did the authors conduct and report visual analysis and appropriate statistical evaluation?
6. Was attrition (or lack thereof) reported/addressed? Were all participants who experienced both baseline and intervention conditions included?
7. Considering the potential within the study design, were appropriate methods for controlling confounding variables and limiting potential biases used?