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Measuring the Effects of Physical Exercise On Stereotypic Behaviors in Autism: Using Hierarchical Linear Model

Christopher W. Tarr[1*], Karen Larwin[2] and Ashlea Rineer-Hershey[3]

*Correspondence: cwtarr@hotmail.com

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[1]Slippery Rock University of Pennsylvania, 351 Lincoln Dr. Pittsburgh, Pa 15241, USA.
[2]Youngstown State University, USA.
[3]Slippery Rock University of Pennsylvania, USA.

Abstract

Individuals with autism experience the core symptoms of delays in communication, delays in social skills, and the engagement in repetitive and restrictive patterns of behavior. Physical exercise has shown the ability to positively impact the core symptoms of autism. Specifically, research has demonstrated the ability to reduce stereotypic behaviors in individuals with autism. The current investigation used the Hierarchical Linear Model, an enhanced type of meta-analysis, to analyze data retrieved from single-subject research design studies to identify possible moderators that increase the effectiveness of the physical exercise intervention on individuals with autism that display stereotypic behaviors. This research assessed three key areas: if different types of stereotypic behaviors responded differently to physical exercise, if different types of physical exercise are more effective in reducing stereotypic behaviors, and if different durations of exercise sessions are more effective in reducing stereotypic behaviors. The results of the current study demonstrated that type of physical exercise is a significant moderator and that types of stereotypic behaviors and duration of exercise sessions are not significant moderators to the effectiveness of physical exercise on reducing stereotypic behaviors in autism.

Keywords: Autism Spectrum Disorder, Intervention, Stereotypic Behaviors, Physical Exercise, Hierarchical Linear Model

Introduction

Autism is considered a neurodevelopmental disorder. The Diagnostic and Statistical Manual 5th Edition (2013) requires that individuals with autism demonstrate the core symptoms of persistent impairment in reciprocal social communication and social interaction, they must engage in restricted, repetitive patterns of behavior, interests, or activities [1]. It is suggested that autism is the fastest growing disability on the planet [2] and it is considered to be one of the most debilitating [3].

Autism is a very diverse and complex disorder. There is no known cure and there is no known single treatment. Individuals with autism often work with a team of professionals that consists of speech therapists, occupational therapists, developmental therapists, physical therapists, behavioral therapists, special education supports, and some may require medication management services. The focus of many behavioral therapies is to increase appropriate skills and decrease unwanted, problem behaviors. This is often accomplished by using a combination of what are referred to as comprehensive treatment models, treatment packages or treatment systems and focused interventions. Comprehensive treatment models consist of a set of practices designed to achieve a broad learning or developmental impact on the core features of autism. Focused intervention practices are designed to address a single skill or goal of a learner with autism.

The National Clearinghouse on Autism Evidence and Practice (NCAEP) and the National Standards Project (NSP) have developed criteria to identify interventions as evidence-based when working with individuals with autism. The NCAEP and the NSP recognize physical exercise as an evidence-based practice for individuals with autism. Research has shown that individuals with autism benefit physically and psychologically from physical exercise. Individuals with autism have experienced physical improvements by way of increases in muscular strength,

endurance, physical appearance, and decreases in percent body fat and body mass index [4-6]. They have also experienced increases in self-confidence [4].

There is a growing body evidence for the effectiveness of physical exercise on the core symptoms of autism. DeJesus et al. (2020) conducted a systematic review on the effectiveness of dance on the core symptoms of autism. DeJesus et al. (2020) concluded that dance had a positive impact on social skills, behavior, and communication skills. Chan et al. (2020) conducted a meta-analysis on the effects of physical activity on communication and social functioning in children and adolescents with autism. Chan et al. (2020) concluded that physical activity is an effective intervention to improve communication and social skills in children and adolescents with autism. Finally, Tarr et al. (2020) and Ferreira et al. (2019) conducted meta-analyses on the effectiveness of physical exercise in reducing stereotypic behaviors in individuals with autism. Both, Tarr et al. (2020) and Ferreira et al. (2019) concluded that physical exercise is an effective method to reduce stereotypic behaviors in individuals with autism.

Stereotypic behaviors, a type of repetitive pattern of behavior, are present in nearly 90% of individuals with autism [11]. Lee et al. (2007) reported that behaviors, such as stereotypic behaviors, may create social stigma and reduce the number of opportunities for full societal integration. Stereotypic behaviors may warrant intervention if the behaviors are isolating an individual from his or her peers and if the behaviors are harmful to the individual with autism or others in the immediate environment [13].

Physical exercise has a long history of evidence in reducing stereotypic behaviors in individuals with autism. Watters and Watters (1980) were the first to use antecedent-based physical exercise as an intervention to decrease stereotypic behaviors in students with autism. Antecedent-based physical exercise intervention requires individuals to engage in the intervention prior to the recording of the desired behavior. The researchers studied the effects of antecedent physical exercise on stereotypic behaviors of five children with autism within the school setting. Watters and Watters (1980) demonstrated that 8-10 minutes of exercise was sufficient to decrease stereotypic behaviors in five students with autism.

The results of Watters and Watters (1980) have been replicated numerous times. Several studies have demonstrated that physical exercise can reduce stereotypic behaviors in people with autism. These studies have revealed a few common themes. First, studies consistently demonstrate that physical exercise does reduce stereotypic behaviors in individuals with autism [14-26]. Second, a number of studies have demonstrated that vigorous exercise is more effective than mild exercise in reducing stereotypic behaviors [15,16,19,21,27]. Finally, a number of studies have shown that physical exercise reduces stereotypical behaviors for short periods of time. Studies have shown that single bouts of physical exercise reduce stereotypical behaviors for 90-120 minutes before

returning to baseline levels [21,28,29].

Despite the common themes, these studies have included very heterogeneous characteristics. Various physical exercises were implemented. For example, studies have used preference-based exercises [25,30], exergaming exercise [24], kata techniques [26], hydrotherapy [31], exercise bike, stair stepper, lifting weights [19], roller skating [18], and swimming [23]. Although the effects of various exercises were studied, all were successful in reducing stereotypic behaviors.

Various durations of exercise have been successful in decreasing stereotypic behaviors as well. Celiberti et al. (1997) demonstrated success with bouts of exercise that lasted 6 minutes per session. Burns and Ault (2009) demonstrated success in reducing stereotypic behaviors with bouts of exercise that lasted 5-8 minutes. Watters and Watters (1980) were successful in using physical exercise to decrease stereotypic behaviors with 8-10-minute acute bouts of exercise. Powers et al. (1992) and Morrison et al. (2011) found success with 10-minute bouts of exercise. Kern et al. (1982) were successful in using acute bouts of exercise that lasted 5-20 minutes in length. A number of studies used 15-minute bouts of exercise [16,27,19,30,32]. Many studies exercised participants for 20 minutes per exercise session [19,20,24]. Yilmaz et al. (2004) had participants exercise for 60 minutes per session. While Bahrami et al. (2012), required participants to exercise for 30-90 minutes per exercise session.

Finally, studies have described several different topographies of stereotypic behaviors ranging from common body rocking [14,16,19,20,25,26,27,28,29,32] to more bizarre eye gazing stereotypies [15,16,21,26,27]. Levinson and Reid (1993) studied the effectiveness of physical exercise on categories of stereotypic behaviors titled motor, vocal/oral, and other. Celiberti et al. (1997) studied the differing effects of physical exercise on two categories of stereotypies: visual and physical stereotypies.

To the knowledge of this research team, only Tarr et al. (2020) and Ferreira et al. (2019) have synthesized these heterogeneous studies and have conducted meta-analyses on the effects of physical exercise on stereotypic behaviors in individuals with autism. The current study synthesized available data from existing single-subject research design studies by using the Hierarchical Linear Model (HLM). Inherently, HLM can correct for some of the limitations of meta-analysis studies. Meta-analysis research synthesizes information within three hierarchical levels; participant, procedure, and results [33]. When analyzing data with such hierarchies, statistical techniques that account for these hierarchies is essential. HLM is a complex form of ordinary least squares regression that accounts for data at different hierarchies [33]. HLM allowed this research team to analyze variance among outcome variables when the predictor variables were at varying hierarchical levels [33]. The current investigationutilized HLM to explore the following research questions:

1. What is the overall effect of physical exercise on stereotypic behaviors in individuals with autism?

2. Is there a differing effect of physical exercise on vocal and motoric stereotypic behaviors in individuals with autism?
3. What is the effect of exercise type on stereotypic behaviors in individuals with autism?
4. What is the effect of exercise duration on stereotypic behaviors in individuals with autism?

Methods
Inclusion Criteria
The current investigation established the following inclusion criteria: (1) The research article must be written in English. (2) The research article must have been written between the years 1980 and beyond; (3) The research must include antecedent physical exercise as the independent variable; (4) The research must include stereotypic behaviors as the dependent variable; (5) The research must include individuals diagnosed with an autism spectrum disorder who are between the ages of 3 and 14 years old; (6) The study must be a single-subject design study that included a functional analysis to determine the function or functions of stereotypic behaviors; and (7) The research must include the effects on stereotypic behaviors attributed to physical exercise interventions expressed quantitatively so that effect sizes can be calculated.

Search Sources
The current investigation used searched the following sources to identify articles to include in this study: (1) PsycInfo; (2) PubMed; (3) Web of Science. This researcher also searched ProQuest and Google Scholar. Journal reviews: (1) *Focus on Autism and Other Developmental Disabilities* and (2) *Journal of Applied Behavior Analysis*. This researcher also searched the reference pages of relevant research articles.

Search Terms
The current investigation used the following search terms to locate articles to include in this study: physical exercise, physical activity, stereotypic behaviors, self-stimulatory behaviors, self-stimulation, restricted and repetitive behaviors, autism, autism spectrum disorder, pervasive developmental disorder, Asperger Syndrome.

Data Extraction
This research team used the ScanIT software to extract the pre intervention and post intervention data points from the graphs of the researchers who did not respond to this researcher. Once the data points were extracted this research team calculated the mean pre intervention scores, mean post intervention scores, and their respective standard deviations using Microsoft excel. Once the mean pre and post intervention, and standard deviation scores were calculated effect sizes via the Tau-U method were calculated.

Analysis of Effect Sizes Estimates
The individual effect size estimates for each of the single subject design studies was calculated using the Tau-U non-overlap method. According to Parker, et al. (2011), Tau-U is expansion of Tau, but includes an adjustment for baseline time trends, which take into consideration the number of observations in each phase as well as the expected direction of improvement (increase or decrease in the observation values). Tau-U is computed:

$$\text{Tau-U} = \frac{1}{mn}\left(\sum_{i=1}^{m}\sum_{j=1}^{n} w_{ij}^{AB} - \sum_{i=1}^{m-1}\sum_{j=i+1}^{m} w_{ij}^{AA}\right)$$ Parker, et al. (2011)

In addition to the single subject effect size estimates, Hierarchical Linear Model (HLM) was used to synthesize the results across the studies, in order to understand the overall estimated effect of physical exercise or activity on the stereotypic behaviors. If a significant effect size estimate is revealed for the introduction of physical exercise or activity, the results of this impact will be provide for types of physical exercise/activity (aerobic, skill based, or aerobic and skill based), for the duration of the physical exercise/activity (1 to 4 minutes, 5 to 10 minutes), and for the type of stereotypic behavior measured (motoric, vocal, or both).

Hierarchical Linear Modeling (HLM) is used to assess the relative magnitude of these effects, since the number of sessions (data points) were not consistent across each individual student's measures [34]. Parker et al. (2011) suggests "the degree of sample size sensitivity depends on the absolute magnitude of the baseline slope, with steeper slopes leading to increased sensitivity" (p.1). The HLM will eliminate this potential bias by allowing for the appropriate adjustments based on the number of sessions on mean effect size data. HLM is one analytical approach that has been found to stable and appropriate for conducting meta-analytic investigations with single-case data [35].

Results
A total of *n*=33 articles specifically studied the effects of physical exercise on stereotypic behaviors. Six of the *n*=33 articles met all inclusion criteria into this study. The single subject design studies included *n*=13 participants. Ten of the participants were male and three were female. The total age range of the males and females combined was 3-14 years old. The total age range for the males was 3-14 years old. The age range for the females was 8-12 years old. The individual study results are provided in **Table 1**.

As indicated in **Table 1**, 14 of the individual activities resulted in significant effect size estimates, while 18 did not. In order to understand the overall impact of the introduction of physical exercise or activity, HLM is used to synthesize these mixed results into one overarching effect size estimate. The model used to produce an effect size estimate for all of the studies as well as three potential moderator variables is stated:
Level-1 Model
$$OUTCOME_{ij} = \beta_{0j} + \beta_{1j}*(SESSION_{ij}) + \beta_{2j}*(PHASECD_{ij}) + r_{ij}$$

Table 1. TAU-U estimates for individual measures by study.

Study Measure	Pairs	TAU_U	*sd*	z	*p*
Currier (2012) Motoric	36	-0.11	0.35	-0.32	0.749
Currier (2012) Vocal	36	-0.36	0.35	-1.04	0.298
Lee(2013) Vocal Thomas	**64**	**-0.66**	**0.30**	**-2.21**	**0.027**
Lee(2013) Vocal Aidan	**64**	**-0.63**	**0.30**	**-2.10**	**0.036**
Lee(2013) Vocal Blake	64	-0.39	0.30	-1.31	0.189
Lee (2013) Motoric Thomas	64	-0.56	0.30	-1.89	0.059
Lee (2013) Motoric Aidan	64	-0.38	0.30	-1.26	0.208
Lee (2013) Motoric Blake	64	-0.48	0.30	-1.63	0.104
Mays(2013) Allison 1	**25**	**-1.00**	**0.38**	**-2.61**	**0.009**
Mays(2013) Allison 2	**25**	**-1.00**	**0.38**	**-2.61**	**0.009**
Mays(2013) Allison 3	**25**	**-0.88**	**0.38**	**-2.30**	**0.022**
Mays (2013) Boyd 1	**25**	**-0.88**	**0.38**	**-2.30**	**0.022**
Mays (2013) Boyd 2	**25**	**-0.88**	**0.38**	**-2.30**	**0.022**
Mays (2013) Boyd 3	**25**	**-1.00**	**0.38**	**-2.61**	**0.009**
McLaughlin(2010) Motoric Bill	**42**	**-0.95**	**0.33**	**-2.86**	**0.004**
McLaughlin(2010) Motoric Larry	180	-0.11	0.23	-0.46	0.643
McLaughlin(2010) Motoric Quinn	**200**	**-0.61**	**0.23**	**-2.68**	**0.007**
McLaughlin(2010) Mini Larry	**144**	**-0.55**	**0.25**	**-2.24**	**0.025**
McLaughlin(2010) Mini Bill	**12**	**-1.00**	**0.47**	**-2.12**	**0.034**
McLaughlin(2010) Mini Quinn	84	-0.11	0.29	-0.37	0.711
McLaughlin(2010) Vocal Larry	20	-0.50	0.41	-1.22	0.221
McLaughlin(2010) Vocal Bill	42	0.24	0.33	0.71	0.475
McLaughlin(2010) Vocal Quinn	50	-0.10	0.33	-0.31	0.760
McLaughlin(2010) V Mini Larry	18	0.00	0.43	0.00	1.000
McLaughlin(2010) V Mini Bill	**12**	**-1.00**	**0.47**	**-2.12**	**0.034**
McLaughlin(2010) VMini Quinn	21	-0.29	0.42	-0.68	0.494
Morrison et al (2011) Steve	36	-0.67	0.35	-1.92	0.055
Morrison et al (2011) Beth	36	0.08	0.35	0.24	0.810
Neely et al (2015) Brief Ally	**25**	**-1.00**	**0.38**	**-2.61**	**0.009**
Neely et al (2015) Brief Chad	25	-0.68	0.38	-1.78	0.076
Neely et al. (2015) Satiation Ally	30	0.10	0.37	0.27	0.784
Neely et al. (2015) Satiation Chad	20	-1.00	0.41	-2.45	0.014

Note: Bold indicates significant effect size estimates

Level-2 Model
$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(EXERCISE_j) + \gamma_{02}*(DURATION_j) + \gamma_{03}*(STEROTYP_j) + u_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$

Mixed Model
$$OUTCMM_{ij} = \gamma_{00} + \gamma_{01}*EXERCISE_j + \gamma_{02}*DURATION_j + \gamma_{03}*OUTCMTY_j$$
$$+ \gamma_{10}*SESSION_{ij}$$
$$+ \gamma_{20}*PHASECD_{ij}$$
$$+ u_{0j} + r_{ij}$$

The results of the estimation produced an excellent estimate of reliability for the intercept α =0.974. The full results for the models are provided in **Table 2**.

Based on the results presented in **Table 2**, the overall impact of the intervention is a moderate significant effect of -.43. This phase effect is significant. The average level of response is (outcome) [exp(45.58 + -.434387)=|4.04|] during treatment. The results also indicate that the number of sessions did not have a significant impact on the overall outcome. The average rate of change per session is -3.01 (B10). This increase is not significant because the p value is >.05 therefore the baseline is flat and suggesting that there is no change over time. Therefore,

Table 2. HLM Full Model Results.

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	48.58	21.88	2.22	34	0.033
EXERCISE, γ_{01}	**-16.14**	**4.22**	**-3.83**	**34**	**<0.001**
DURATION, γ_{02}	6.57	9.20	0.71	34	0.480
STEROTYP, γ_{03}	1.24	5.39	0.23	34	0.820
For SESSION slope, β_1					
INTRCPT2, γ_{10}	-3.01	1.72	-1.75	487	0.081
For PHASECD slope, β_2					
INTRCPT2, γ_{20}	-0.43	0.17	-2.51	487	0.012

Note: Bold indicates significant effect size estimates

the final estimate of response to exercise is stated Log(Y)= 48.58 -.4344, providing an effect of -4.04 on the motoric or vocal measure. Type of stereotypic behaviors and duration were not significant moderators. However, exercise type was (*p*<.001) was found to be a significant moderator. Phase by exercise type is computed as [Exp(phase + exercise level)] providing the following results for the three exercise types: Aerobic only=|5.68e24|; Skill only=|6.0e14|, and Aerobic and Skill= |16.4|. This indicates that the greatest impact is found with the combination of aerobic and skill.

Discussion

The purpose of the current study was to further the findings of Tarr et al. (2020) and Ferreira et al. (2019) by analyzing data from single-subject research design studies on the effects of physical exercise on stereotypic behaviors in individuals with autism. In particular, this study used HLM to assess the overall effect of physical exercise on stereotypic behaviors, the potential differing effects of physical exercise on different topographies of stereotypic behaviors, the potential differing effects of different types of exercise on stereotypic behaviors, and the potential differing effects of different durations of physical exercise on stereotypic behaviors. Overall, the effect of physical exercise on stereotypic behaviors in the current investigation was a moderate significant effect of *d* = -.43. The current investigation provides further evidence that physical exercise does have the ability to decrease stereotypic behaviors in individuals with autism.

In regards to type of stereotypic behavior, exercise type, and duration of exercise sessions, only exercise type was found to be a significant moderator. The current investigation concluded that aerobic only exercise produced =|5.68e24|. Skill-based exercises only produced =|6.0e14|. The combination of aerobic and skill-based exercises = |16.4|. The current investigation concluded that the greatest impact is found with the combination of aerobic and skill-based exercises. The moderators; type of stereotypic behavior and duration of exercise sessions were found to not be significant moderators.

The results of the current study indicate that a combination of aerobic and skill-based exercise is the most efficient type of exercise to reduce stereotypic behaviors in individuals with autism. This finding adds to previous research. Most of the research studying the effects of physical exercise on stereotypic has focused on the intensity and duration of the physical exercise and not the specific type of physical exercise [15,16,19,21,27]. More recently, Olin et al. (2017) studied the effects of exercise dose on stereotypic behaviors in autism. Olin et al. (2017) assessed stereotypic behaviors following bouts of light intensity exercise sessions with durations of 10 and 20-minute sessions and high intensity sessions with durations of 10 and 20 minute sessions. The results of Olin et al. (2017) demonstrated that bouts of light exercise for a duration of 10 minutes had the greater effect on reducing stereotypic behaviors. Interestingly, the results of Olin et al. (2017) demonstrated that bouts of high intensity exercise for a duration of 20 minutes increased stereotypic behaviors.

The effectiveness of skill-based exercises is supported in neurobiological and neuroscience research. Research has demonstrated that sports drills, skill-based, motor fitness, and/or coordination training specifically impacts the basal ganglia, parietal lobe, and cerebellum in children and adults. Interestingly, various abnormalities and dysfunction within the basal ganglia [42,43,44] and the cerebellum [42,45] structures of the brain have been linked to the expression of stereotypic behaviors in individuals with autism. Becker et al. (2016) accumulated and reviewed studies that involved the exercise induced changes within the basal ganglia. Becker et al. (2016) reviewed a total of seven studies. Five of the studies involved adult participants. Whereas, only two study involved children. Becker et al. (2016) concluded that aerobic physical exercise has shown the ability to positively affect the structure of the basal ganglia. Becker et al. (2016) also concluded that motor fitness/coordination training physical exercise has shown a greater ability to positively affect the structures of the basal ganglia. Chaddock et al. (2010) demonstrated that preadolescents who participated in regular physical exercise showed

an increase in basal ganglia volume. Niemann et al. (2014) demonstrated that aerobic exercise combined with coordination training increased basal ganglia volume in older adults. Finally, Petzinger et al. (2015) defined skilled aerobic exercise as exercise that is goal-oriented movement in which temporal and spatial accuracy is important for achieving the exercise objectives. Petzinger et al. (2015) demonstrated that skilled aerobic exercise increases the number neuronal synapses within the basal ganglia where aerobic exercise does not.

The results of the current study are congruent with research associated with the effects of physical exercise on the structures and functioning of the brain, specifically the basal ganglia. A combination of aerobic and skill-based exercise routines has a greater positive impact on the basal ganglia. It may not be sufficient to claim that physical exercise has the ability to reduce stereotypic behaviors in autism. It may require that we begin to develop specific exercise routines that target specific areas of the brain. It may be even more appropriate to develop physical exercise routines that engage various areas of the brain simultaneously.

Limitations of the Study

The major limitation of the current study is the small number of research articles that met criteria for this study. A thorough search only produced six articles that met the inclusion criteria for this study. However, the method of analyses used was developed specifically for small-sample studies with individual level analyses. And, while a small number of studies is a potential limitation, it speaks to the need for additional research in the arena of aerobic and skill-based activity on stereotypic behaviors with both individual students and groups of students. A second major limitation is inherent within all meta-analytic type research is that the researcher is limited to only the information presented by each study. The current investigation incorporated those reported aspects of each study that were most likely to be related to the overall impact based on the extant autism research.

Future Research

Continued research is needed on the effects of physical exercise on stereotypic behaviors in individuals with autism. There have been a limited number of studies conducted on the effects of physical exercise on stereotypic behaviors in autism since Watters and Watters (1980). Future research is needed to identify specific characteristics of physical exercise routines that efficiently and effectively reduce stereotypic behaviors in individuals with autism. Future research is needed to decipher if certain stereotypic behaviors originate in different structures of the brain and if specific types of exercise can be prescribed to efficiently target that particular area.

Conclusion

The current study used the HLM statistical model to gain information on the effects of physical exercise on stereotypic behaviors in individuals with autism. The results of the current study demonstrate that physical exercise is effective in decreasing stereotypic behaviors in individuals with autism. Specifically, a combination of aerobic and skill-based exercise has the greatest impact on the reduction of stereotypic behaviors. This is important for attempting to identify characteristics of physical exercise routines that effectively and efficiently decrease stereotypic behaviors. The results of the current study adds further evidence that physical exercise is an evidence-based practice for improving the core symptoms of autism. Clinicians, therapists, and teachers should consider physical exercise as an effective nonpharmacological intervention for reducing stereotypic behaviors in individuals with autism.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	CWT	KHL	AR
Research concept and design	√	√	--
Collection and/or assembly of data	√	--	--
Data analysis and interpretation	√	√	--
Writing the article	√	√	√
Critical revision of the article	√	--	√
Final approval of article	√	√	√
Statistical analysis	--	√	--

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