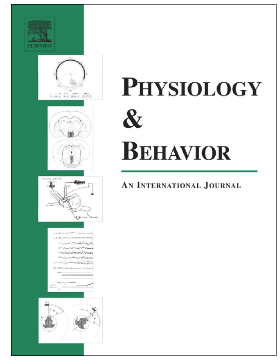

Use of technology to facilitate physical activity in children with autism spectrum disorders: A pilot study

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Use of Technology to Facilitate Physical Activity in Children with Autism Spectrum Disorders: A Pilot Study

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Abstract

Deficits in social behavior and communication skills are correlated with reduced gross motor skills in children with autism spectrum disorders (ASD). The *ExerciseBuddy* application (EB app) was designed to communicate these motor skills to those with ASD and integrates evidence-based practices such as visual support and video modeling supported by The National Professional Development Center on Autism Spectrum Disorders. The purpose of this study was to determine the effectiveness of the EB app in facilitating increased physiologic responses to physical activity via a continuous measurement of energy expenditure and heart rate versus practice-style teaching methods in children with ASD. Six children, ages 5 to 10 years, diagnosed with ASD were recruited. Each participant performed a variety of locomotor or object control skills as defined by the *Test of Gross Motor Development-2* once per week for 4 weeks. Motor skills were communicated and demonstrated using either practice-style teaching methods or the instructional section of the EB app. Energy expenditure and heart rate were measured continuously during each 12-minute session. A Wilcoxon signed-rank test was performed to assess any differences between the use of the app and practice-style teaching methods. The use of the EB app elicited greater values for peak energy expenditure (p = 0.043) and peak heart rate response (p = 0.028) while performing locomotor skills but no differences were observed while performing object control skills. Similarities were observed with average physiologic responses between the use of the EB app and practice-style teaching methods. The use of the EB app may allow for a greater peak physiologic response during more dynamic movements and a similar average cardiovascular and metabolic response when compared to practice-style teaching methods in children with ASD.

Keywords: autism, energy expenditure, exercise, heart rate, physical activity, video modeling

1. Introduction

According to the Centers for Disease Control and Prevention, 1 in 68 children are currently diagnosed with autism spectrum disorder (ASD) in the United States [1]. Although 5 times more prevalent in males, ASD occurs in all ethnicities and socioeconomic groups. Children with ASD have repetitive behaviors, deficits in social and communication skills, and motor development delays that manifest prior to 3 years of age [2,3]. Teachers and families must therefore consider alternative methods to support the physical and gross motor development of those with ASD. The use of various modalities of physical activity have recently received much attention as a method to improve the quality-of-life in children with ASD [4,5].

1.1 Physical Activity

A growing number of children with ASD may not possess the skills needed to be physically active and participate in sport and recreational teams in their local school or community [6]. Physical activity can be an inexpensive and safe option for the promotion of overall health and quality-of-life by providing physical and cognitive benefits. To improve cardiorespiratory fitness, prescribing a proper exercise intensity level is crucial. Several methods, including percentages of age-predicted maximum heart rate and relative energy expenditure, are commonly used to quantify light, moderate and vigorous intensities of exercise [7]. It has been reported that children with ASD do not exercise at a moderate-to-vigorous level as frequently as their typically developing peers [8] and may be at greater risk for developing cardiovascular, pulmonary, or metabolic diseases [9]. Indeed, the prevalence of obesity in children with ASD is 30.4% compared to 23.6% in children without ASD [10]. However, in children ages 9 to 11 years with ASD, body mass index (BMI) is decreased and time spent engaging in moderate-to-vigorous physical activity is increased when compared to children ages 12 to 18 years with ASD [11]. The ability to quantify physiologic responses to exercise in children younger than 9 years of age may be a useful tool for prescribing physical activity throughout childhood and adolescence. Additionally, physical activity may decrease the incidence of behavioral outbursts and episodes of aggression in children with ASD [12]. There are a variety of teaching modalities, such as video modeling, that may increase physical activity levels for children with ASD.

1.2 Video Modeling

Instruction during physical activity typically relies heavily on verbal communication and social interactions. These 2 behavioral aspects may be difficult to execute for those with ASD. With more effective instructional methods, children may have longer periods of sustained engagement during periods of physical activity. Children with ASD have strengths in processing visual information but may not retain or be able to recall verbal instructions [13]. Video modeling is an evidence-based practice for children with ASD that includes the use of a model (e.g., animated self, peer) consistently demonstrating a skill [14]. This alternative mode of instruction can be displayed on a computer, television monitor, or on various hand-held devices including a tablet or phone. It has been reported that teachers may prefer tablets and video strategies over non-electronic, picture-based systems due to ease of use, less preparation time, and improved communication with their students [15]. Additionally, video modeling has been reported to be more time and cost efficient than practice-style teaching methods [16]. Practice-style is one of the most common teaching strategies used during physical activity. Practice-style instruction begins with a demonstration and description of what is to be achieved. The students then practice the skill, and the teacher observes their performance and offers feedback [17].

The use of video modeling may allow children with ASD to engage in more appropriate behaviors related to a given task and learn more motor skills [18]. While researchers have reported conflicting results [19], Bellini and Akullian concluded that video modeling is an effective strategy because there is a removal of external stimuli [20]. This may allow for enhanced focus and less distractions for children with ASD. Video modeling also allows the learner to view the same model and demonstration repeatedly, helping to improve learning and retention [21]. When compared to tasks using video modeling, tasks using live modeling took 274% longer to complete [17]. In those with ASD, the ability to focus and complete activities in an appropriate time frame utilizing video modeling may elicit a greater total value for energy expenditure and greater heart rate response when compared to live modeling of similar duration. No empirical studies to date have included an examination of this effect.

1.3 ExerciseBuddy Application

Available on Apple and Android handheld devices, the *ExerciseBuddy* application (EB app) is based on a visual exercise system for children with ASD. Pioneered by David Geslak, the EB app was developed to provide training techniques for teachers and parents of individuals with ASD. The EB app integrates evidence-based practices such as video modeling supported by The National Professional Development Center on ASD [22,23] and contains over 180 exercise videos of varying duration. Using the EB app, parents and teachers, including those with little to no experience teaching physical activities, may provide physical activity instruction and motor skill practice to their child with ASD.

1.4 Purpose

The purpose of this study was to determine the effectiveness of the EB app in facilitating increased physiologic responses to physical activity via a continuous measurement of energy expenditure and heart rate versus practice-style teaching methods in children with ASD.

2. Methods

2.1 Participants

Purposive sampling was used to recruit 6 children, 5 to 10 years of age, diagnosed with ASD from a university outreach program designed to improve gross motor skills in children with developmental delays. Participants attended the outreach program once per week for 4 consecutive weeks with data collected in 12-minute periods. All procedures were approved by the university's institutional review board. All parents gave written, informed consent and all children gave verbal assent prior to the start of all procedures.

2.2 Entry Session

The parents of the participants were asked to complete a medical history questionnaire and an informed consent on behalf of their child for enrollment into the study. Inclusion criteria were chronological age of 5 to 10 years, a diagnosis of ASD, a severity level rating of 1 (i.e., needs support) or 2 (i.e., needs substantial support) [2], and at least a total raw score of '2' on the *Test of Gross Motor Development-2* (*TGMD-2*) [24]. The *TGMD-2* is comprised of 2 subtests: object control skills and locomotor skills. Each subtest contains 6 skills that are designated to help evaluate functional motor skills. Each skill includes 3 to 5 performance criteria. When scoring the *TGMD-2*, a '1' is recorded when the performance criteria are demonstrated and a '0' is recorded when the performance criteria are not demonstrated. Participants needed to score at least a '1' on both the locomotor and object control subtests to be enrolled in the study. The researchers administered the *TGMD-2* to all participants.

At the start of the entry session, verbal assent (i.e., participants provided verbal affirmation of their willingness to participate in the day's activities when asked verbally by the researcher) was obtained. The assent process was recorded by hand by at least two researchers before any procedures were started for the day. During the session, the participants were familiarized with the protocol and the equipment used in the study. The participant's height and weight were measured with weight assessed using a digital scale and height assessed using a stadiometer (Detecto Scale Company, Webb City, MO). Body mass index (BMI) was calculated from these measures. The participants were then shown the Actiheart monitor (CamNTech Inc., Boerne, TX), the device used to measure energy expenditure and heart rate, and the accompanying surface electrodes. During the remainder of the entry session, the monitor and electrodes were worn by all of the participants for at least 12 minutes. The two electrodes, placed on the chest, served as a connection between the monitor and participant. The Actiheart monitor has been validated to measure light-, moderate- and vigorous-intensity levels of physical activity in children with chronic disease [25,26]. Participants were instructed that 2 stickers (i.e., the electrodes) would be placed on their chest to measure their heartbeat. The monitor was then attached to the participant via connectors on the electrodes. The participants were instructed not to interfere or "touch" the stickers on their chest. Only one participant indicated sensitivity toward electrodes during the entry session. For this participant, the paraprofessional was given electrodes to place on the participant's chest (without the monitor) once per day, for a minimum of 12 minutes, to be completed on 4 consecutive days prior to the start of the first physical activity session. This was the only adverse response to the placement of the electrodes and monitor throughout the study.

2.3 Physical Activity Sessions

Prior to the start of each physical activity session, all experimental procedures were reviewed with the participants using age-appropriate verbiage, after which, the participants were re-assented in a similar manner as the entry session. The Actiheart monitor and surface electrodes were then fit on the participants. The monitor was worn throughout the duration of the physical activity. Heart rate (bpm) was measured continuously and energy expenditure (METs) was accurately estimated using heart rate and accelerometry data measured via the Actiheart monitor during the sessions to assess the intensity of the physical activity.

Prior to testing, each participant sat quietly for approximately 12 minutes. During this time, the participants were allowed to select from 12 age-appropriate apps, uploaded to iPads (Apple Inc., Cupertino, CA), that did not incorporate physical activity (e.g., Lazoo Zoo [Lazoo Worldwide Inc., New York, NY], Toca Monsters [Toca Boca Inc., San Francisco, CA], Friends [Sago Sago Toys Inc., Toronto, ON]). Participants were then asked to perform their motor tasks for that day's physical activity sessions. During each session, participants performed a protocol that included a teaching method (i.e., practice-style, EB app) and a motor task (i.e., object control, locomotor). All motor tasks performed were identical between teaching method conditions (e.g., each child performed identical object-control skills for the EB app condition and the practice-style condition). Each trial lasted 2 minutes, with the researcher demonstrating or the EB app providing the activity before the start of the trial. There were no opportunities for the participant to practice the activity before the start of each trial. The EB app was purchased from the virtual Apple store and uploaded to iPads. The EB app was used to incorporate an auditory countdown (i.e., 5, 4, 3, 2, 1) and visual feedback (e.g., reinforcement, technology aided instruction, video modeling) for the participants [23]. The motor tasks were derived from the performance criteria of the *TGMD-2* test items (see Table 1 for list of activities performed).

INSERT TABLE 1

The practice-style teaching method was used to verbally instruct a skill to be performed, and the participant was asked to produce a response or performance on cue. If necessary, a one-time visual demonstration of the skill was given by an instructor [17]. Both the instructor, through the use of practice-style teaching methods, and the EB App gave 1 general positive feedback statement (e.g., "Nice try"). The protocols were randomized without replacement for each participant. A different combination of teaching method and set of motor tasks was performed each week, resulting in 4 total testing sessions (see Table 2 for a sample study timeline). The duration of physical activity during each session was approximately 12 minutes. For 1 physical activity session, each participant was asked to perform 5 locomotor skills or 5 object control skills. Each skill was performed for 2 minutes. The additional 2 minutes were used for instruction and viewing the video clips from the EB app. All skills were performed on a flat surface.

INSERT TABLE 2

2.4 Statistical Analysis

The independent variable was a combination of teaching method (i.e., practice-style, EB app) and motor task (i.e., locomotor, object control). Average and peak energy expenditure and average and peak heart rate during physical activity in each testing session were measured as dependent variables. A Friedman's test was performed to assess any differences across all four conditions (i.e., practice-style and locomotor; practice-style and object control; EB app and locomotor; EB app and object control). As a follow-up test, a Wilcoxon signed-rank test was performed to assess any differences between the teaching methods and the motor tasks. Results were analyzed using SPSS v.22 (IBM Inc., Armonk, NY) with a significance level of 0.05.

3. Results

Participant demographics and scores from the *TGMD-2* are listed in table 3. There were 5 males and 1 female recruited, ages 6 to 10 years. All participants were classified as normal weight or underweight according to BMI.

INSERT TABLE 3

There was a difference in average energy expenditure (p = 0.012) and peak energy expenditure (p = 0.009) across all conditions. There was also a difference in average heart rate response (p = 0.015) and peak heart rate response (p = 0.001) across all conditions.

Differences in energy expenditure and heart rate between the 2 teaching methods while performing locomotor skills and while performing object control skills are presented in table 4. There were no differences in average energy expenditure when using the EB app versus practice-style instruction with regard to locomotor (p = 0.893) or object control skills (p = 0.249). There were also no differences in average heart rate when using the EB app versus practice-style instruction with regard to locomotor (p = 0.463) or object control skills (p = 0.600).

The EB app elicited a greater peak energy expenditure from the participants versus practice-style instruction while performing locomotor skills (p = 0.043) but there was no difference between the teaching methods while performing object control skills (p = 0.600). With regard to locomotor skills, the EB app also elicited a greater peak heart rate response from the participants versus practice-style instruction (p = 0.028), though this was not true for object control skills (p = 0.753).

INSERT TABLE 4

4. Discussion

The purpose of this study was to determine the effectiveness of the EB app in facilitating increased physiologic responses to physical activity via a continuous measurement of energy expenditure and heart rate versus practice-style teaching methods in children with ASD. There were 2 major findings from this study. While performing locomotor skills, the use of the EB app allowed for a greater peak energy expenditure and heart rate response compared to practice-style teaching methods. However, there were no differences in average energy expenditure or in heart rate responses between the 2 teaching methods independent of the mode of physical activity. Both findings are noteworthy because the implementation of the EB app may be as effective in eliciting similar average cardiovascular and metabolic responses when compared to practice-style teaching. Further, the EB app may be more effective in eliciting greater peak cardiovascular and metabolic responses when compared to practice-style teaching methods. Given these results, teachers and family members, including those without a background in physical activity, could use the EB app to facilitate physical activity for children with ASD. Given the impact of ASD on youth's physical activity behaviors, the EB app appears to be a viable tool for facilitating periods of physical activity as well as higher intensity physical activity, which can lead to improved health and quality-of-life in children with ASD. With young children, the ability to accumulate short bouts of physical activity, inclusive of moderate-to-vigorous intensity levels using the EB app, could improve health by preventing the onset of chronic metabolic conditions, such as obesity, later in adolescence and adulthood.

The average energy expenditure for all participants while performing locomotor skills was 5.0 METs using practice-style teaching methods and 5.1 METs using the app. According to the compendium of energy expenditures for youth, physical activity with an emphasis on locomotor skills elicits the metabolic equivalent of more sports related activities (e.g., swimming, roller skating) and physically demanding activities of daily living (e.g., climbing stairs) [27]. The observed energy expenditure during locomotor activities (e.g., skipping, hopping, galloping, sliding) in this study also correlates with youth walking vigorously [27].

The average energy expenditure for all participants while performing object control skills was 3.6 METs using practice-style teaching methods and 3.4 METs using the app. Physical activity with an emphasis on object control skills elicits the metabolic equivalent of more common activities of daily living (e.g., dressing, making a bed, cleaning a room) and recreational physical activity (e.g., horseback riding) [27].

Energy expenditure and heart rate responses were measured using the Actiheart monitor in this study. This device has been validated during light (0 to 3 METs), moderate (3 to 6 METs) and vigorous (6 or more METs) in both healthy adults [28] and young children with various chronic diseases, including spina bifida [26] and various cardiovascular, pulmonary, orthopedic and neuromuscular diseases [25]. Average energy expenditure values for locomotor and object control skills and peak energy expenditure for object control skills fell within the range identified as moderate-intensity in adults, or 3 to 6 METs [7]. Peak energy expenditure values for locomotor skills fell within the range identified as vigorous-intensity in adults, or greater than 6 METs [7]. When setting proper intensity for exercise in children, the use of adult guidelines to increase aerobic fitness may be appropriate [29,30]. Other authors have suggested a specific training intensity to improve and maintain basic health-related fitness in children at 50% to 60% of maximal heart rate (HR_{max}) [31]. The average heart rate observed in this study was 70% to 75% HR_{max} during locomotor activities, which falls within the interval required to improve and maintain intermediate health-related fitness (i.e., 60% to 75% HR_{max}) in children [31]. The average heart rate observed during the object control activities also fell within the interval to improve and maintain fitness [31]. Given these results and the propensity for youth with ASD to be sedentary [5], it appears appropriate to recommend that teachers and parents consider the use of the EB app to assist children with ASD in meeting recommended daily guidelines for physical activity. Participation in regular physical activity may not only improve aerobic capacity, muscular strength and endurance, flexibility, and body composition [12], it may allow children with ASD to possess a higher quality-of-life and exhibit less stereotypical behaviors (e.g., hand flapping, rocking, spinning) [32]. According to the American College of Sports Medicine, exercise may be divided into bouts lasting 10 or more minutes throughout the day to meet the necessary requirements for daily physical activity [33].

4.1 Limitations

Certain limitations were evident in this study. Although heart rate was used to monitor exercise intensity in this study, the greatest heart rate variability can occur during light-intensity activities in children [34]. The variation of heart rate is thought to be due to a predominating influence of the parasympathetic versus sympathetic autonomic control [34]. An attempt was made to control for environmental influences on heart rate by testing under standardized conditions and at the same time of day. However, it appears that many environmental factors – even under controlled conditions – can add to the parasympathetic control and caused substantial variation in the heart rate response to both modes of physical activity.

Second, maximum exercise effort and maximal oxygen consumption (VO_{2max}) were not measured. As such, exercise intensities in terms of a percentage of HR_{max} or VO_{2max} or expressed as a percentage of HR or VO_2 reserve could not be reported. Third, the study was not sufficiently powered to examine variations in cardiorespiratory responses that may be, at least partially, explained by gender, physical maturity, and body composition. A fourth limitation was that the children had varying diagnoses related to ASD. As such, some children were more mildly affected than others, and functional abilities differed among participants. Results from this study cannot be extrapolated to children who are more severely affected with ASD. Finally, a limitation in this study was the sample population of children of ages 5 to 10 years may not be reflective of those diagnosed with ASD as a whole, particularly as obesity prevalence increases and participation in physical activity decreases from childhood through adolescence [11].

5. Conclusions

The use of the EB app may allow for a greater peak physiologic response during dynamic movements that require locomotor skills and a similar average cardiovascular and metabolic response when compared to practice-style teaching methods using live models in children with ASD. Teachers, family members, and other peers, who may not have a background in teaching physical activity, may use the EB app to communicate appropriate exercise instruction. Thus, the EB app appears to be a viable tool for facilitating physical activity, inclusive of higher intensity physical activity levels. Accumulating short, moderate-to-vigorous physical activity bouts using the EB app could improve health by preventing the onset of chronic diseases, such as obesity, later in adolescence and adulthood.

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Conflict of interest

None of the authors declare any conflicts of interest related to this study.

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Table 1 Locomotor and object control skills used in EB app and practice-style teaching protocols.

Activity Subtest	Skill*	Materials	Directions
Locomotor			
	Run	15.2 m of clear space; 2 cones	"Run as fast as you can from 1 cone to the other"
	Gallop	7.6 m of clear space; 2 cones	"Gallop as fast as you can from 1 cone to the other"
	Hop	4.6 m of clear space; 2 cones	"Hop 3 times on each foot"
	Slide	7.6 m of clear space; 2 cones	"Slide from 1 cone to the other"
	Horizontal jump	Mark off a starting line on a level floor	"Jump as far as you can"
Object Control			
	Striking a stationary ball	1 plastic ball, 10.2 cm in diameter; 1 plastic bat; 1 batting tee	"Hit the ball hard off of the tee"
	Stationary dribble	1 basketball; flat surface	"Dribble the ball 4 times without moving your feet using 1 hand. Stop by catching the ball"
	Catch	1 plastic ball, 10.2 cm in diameter; 4.6 m of clear space	"Catch the ball with both hands when I throw it to you" (participant and tosser are 15 feet apart)
	Kick	1 soccer ball; tape to mark start	"Run and kick the ball hard" (participant and ball are 10 feet apart at start)
	Overhand throw	1 tennis ball; vertical wall; 6.1 m of clear space	"Throw the ball hard at the wall" (participant and wall are 20 feet apart)

*: 2 trials performed for each skill.

Table 2 Sample study timeline.

	Week 2*	Week 3	Week 4	Week 5
Teaching Method	Practice-style	Practice-style	EB app	EB app
Motor Task	Object control	Locomotor	Object control	Locomotor
Duration (min)	12	12	12	12

*: preliminary screening was held during week 1; EB app = ExerciseBuddy application.

Table 3 Participant demographics and raw scores from the *TGMD-2*.

	Age (yrs)	Height (m)	Weight (kg)	BMI (kg/m^2)	*TGMD-2* Raw Scores Locomotor	Object Control	Overall
Mean±s.d.	7.3±2.3	1.31±0.13	29.7±9.7	17.1±2.9	25.2±9.0	18.7±11.8	43.8±19.4
Range	5 – 10	1.09 – 1.45	20.4 – 47.6	14.3 – 22.6	12 – 35	5 – 33	22 – 68

Data are for 5 males, 1 female. BMI = body mass index; s.d. = standard deviation; *TGMD-2: Test of Gross Motor Development-2*.

Table 4a Energy expenditure and heart rate responses while performing locomotor skills instructed using practice-style teaching methods and the ExerciseBuddy application.

	Locomotor Activity						
	Practice-Style Method	Min	Max	EB App	Min	Max	*p*-value
EE_{avg} (METs)	5.0±1.8	2.8	7.4	5.1±1.8	2.8	7.5	0.893
EE_{peak} (METs)	6.8±1.8	4.4	9.2	7.2±2.2*	4.4	10.3	0.043
HR_{avg} (bpm)	152±25	113	173	154±24	119	183	0.463
HR_{peak} (bpm)	174±29	119	193	187±22*	153	204	0.028

Values are mean±s.d. * = significantly different from practice-style teaching method. EB App = ExerciseBuddy application; EE_{avg} = average energy expenditure; EE_{peak} = peak energy expenditure; HR_{avg} = average heart rate; HR_{peak} = peak heart rate.

Table 4b Energy expenditure and heart rate responses while performing object control skills instructed using practice-style teaching methods and the ExerciseBuddy application.

	Object Control Activity						
	Practice-Style Method	Min	Max	EB App	Min	Max	*p*-value
EE_{avg} (METs)	3.6±0.4	2.9	4.0	3.4±0.7	2.4	4.4	0.249
EE_{peak} (METs)	4.7±0.3	4.1	5.0	5.1±1.9	3.2	7.8	0.600
HR_{avg} (bpm)	130±14	109	143	127±15	107	145	0.600
HR_{peak} (bpm)	149±19	117	169	149±19	119	167	0.753

Values are mean±s.d. EB App = ExerciseBuddy application; EE_{avg} = average energy expenditure; EE_{peak} = peak energy expenditure; HR_{avg} = average heart rate; HR_{peak} = peak heart rate.

Highlights

- The ExerciseBuddy application is an alternative to practice style teaching methods.
- The app may be an effective teaching tool for children with Autism Spectrum Disorders.
- A greater peak energy expenditure can be found using the app during dynamic exercise.
- A greater peak heart rate can be found using the app during dynamic exercise.
- Average exercise energy expenditure and heart rate is similar between the two methods.