Exergaming to Improve Physical and Mental Fitness in Children and Adolescents with Autism Spectrum Disorders: Pilot Study

Claudia L. Hilton1*, Allison Attal2, John R. Best3, Timothy A. Reistetter4, Pete Trapani4 and Diane M. Collins1

1Occupational Therapy & Rehabilitation Sciences Departments, University of Texas Medical Branch, USA
2Occupational Therapy Department, University of Texas Medical Branch, USA
3Djavad Mowafaghian Centre for Brain Health, University of British Columbia, USA
4Fitness for Life & Health, USA

*Corresponding author: Claudia L. Hilton, University of Texas Medical Branch, Occupational Therapy & Rehabilitation Sciences Departments, School of Health Professions, 301 University Blvd, Galveston, TX 77555-1142, USA, Tel: 409-772-3079, Fax: 409-747-1615, E-mail: clhilton@utmb.edu

Abstract

Although not included as core characteristics of autism spectrum disorders (ASD), children and adolescents with this diagnosis often experience executive function (EF) and motor impairments. This study investigated the use of a speed-based exergame called the Makoto arena as an intervention strategy to improve EF and motor performance in 17 school-aged children and adolescents with ASD. All areas of EF improved, with significance in the overall global executive composite and in the metacognition index of the Behavior Rating Inventory of Executive Function. All motor skills improved except fine manual coordination, with significance in strength and agility on the Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition. Participants increased response speed showing a large effect size. Findings suggest that use of exergaming may be a beneficial addition to be included in interventions for children and adolescents with ASD who experience impairments in EF and motor performance.

Keywords

Active video games, Autism spectrum disorders, Executive function, Exergames, Motor skills

Executive Function

EF refers to higher order cognitive processes that are used to guide behavior in a changing environment, and includes the constructs of planning, inhibition, impulse control, working memory, cognitive flexibility, creativity, and initiation of action [19]. EF includes the skills necessary for goal-directed cognition and purposeful activity [20]. EF is also important for being able to inhibit inappropriate behaviors [6]. Without good EF, children and adults may say or do things that are considered to be bizarre or offensive, thus impeding positive social interactions. These skills are also needed in various circumstances, including self-directed learning and emotional regulation, which can contribute to academic success in children [21], and successful participation in adult roles [4]. Deficits in aspects of EF have been replicated by numerous studies of children with ASD [12,13].

Motor Impairment

Motor skills are necessary for many types of human activities, such as self-care, writing, games, sports, dance and recreational activities [22-24]. Motor impairment is recognized as a symptom associated with ASD by the World Health Organization [25]. Motor deficits often associated with ASD may include problems in motor planning, coordination, and an inability to participate in developmentally appropriate activities, which affect the child’s ability to initiate motor activities or switch between motor tasks [15,16,26-28].

Motor impairment has been demonstrated in many studies of children with ASD. Several studies have found that approximately 80%-90% of persons with ASD who were study participants demonstrated some degree of motor impairment such as fine and gross motor planning or coordination challenges, strength or agility problems, dyspraxia, and neurological signs of dysrhythmia, abnormal muscle tone, praxis, and motor impairment [14-17].
Motor impairment has been linked to specific functional skills in children with ASD. Linkenauger, Lemer, Ramenzoni and Proffitt [29] found that, compared with controls, individuals with ASD showed gross motor impairments in relating information about their bodies’ action capabilities to visual information specifying the environment and that the magnitude of these deficits strongly predicted the magnitude of social/communicative impairments in those individuals with ASD. They concluded that social/communicative impairments in ASD may derive, at least in part, from motor deficits. In another study, MacDonald, Lord, & Ulrich [30] determined that fine motor performance skills were predictive of adaptive behavior skill performance (p<0.01), while gross motor performance skills were predictive of daily living skill performance (p<0.05). The authors later determined that greater motor deficits predicted greater deficits in adaptive behavior skills [31].

**Relationship between Executive Function and Comorbidities**

Several studies have shown that EF has a crucial relationship with other autistic comorbidities. Links between EF and repetitive behaviors [32], anxiety [33], and comorbid psychopathology [34] have been identified in children with ASD. Lopez and colleagues [32] compared 17 adults with ASD and 17 controls and found that the occurrence of repetitive behaviors in the group with ASD was strongly correlated with cognitive flexibility, working memory, and response inhibition, all aspects of EF. They postulated that when individuals with ASD experience executive dysfunction, it impairs the ability to produce, plan, and manage behaviors, which results in the atypical behavior associated with ASD. Because engagement in repetitive behaviors acts as a barrier to social and community participation and integration, these results suggest that interventions which improve EF could also have the added positive effect of decreasing repetitive behaviors [33]. Hollocks and associates [33] examined 90 adolescents with ASD between 14 and 16 years of age and found a significant association between poorer executive functioning and higher levels of anxiety. Findings from a study of 70 children and adolescents between age 6 and 16 years diagnosed with ASD by Lawson and associates [34] indicate EF problems as a predictor of comorbid psychopathology (anxiety/depression and aggression/oppositionality) and as crucial intervention targets for potential prevention and mitigation of comorbid symptoms. EF and motor impairment in children may also be related. Studies of typically developing children suggest that EF and motor performance have underlying processes in common that relate to planning, monitoring, and detecting and correcting errors [36-40]. Hartmann, Houwen, & Visscher [41] found that children with intellectual disabilities experience difficulty with EF and motor performance have underlying processes in common that relate to planning, monitoring, and detecting and correcting errors. Findings from a study of 70 children and adolescents between age 6 and 16 years diagnosed with ASD by Lawson and associates [34] indicate EF problems as a predictor of comorbid psychopathology (anxiety/depression and aggression/oppositionality) and as crucial intervention targets for potential prevention and mitigation of comorbid symptoms. EF and motor impairment in children may also be related. Studies of typically developing children suggest that EF and motor performance have underlying processes in common that relate to planning, monitoring, and detecting and correcting errors [36-40].

**Exercise and Cognition in Children with ASD**

Physical exercise has been found to improve cognitive processes, specifically EF, in typically developing individuals [42-44]. Likewise, it has been found to have a positive influence on symptoms seen in children and adolescents with ASD, including improvement in EF and a reduction in repetitive behaviors [45-48]. The mechanism of improvement in these cognitive functions as a result of physical exercise is only partially understood, and is thought to be caused by increased cerebral blood flow, up-regulation of neuroprotective growth factors, and the cardiovascular benefits of exercise, which lead to an improvement in the delivery of oxygen and nutrients [43,46].

Children with ASD often participate in limited physical activities [49] enjoy them less than do typically developing children [50] experience weight gain from medications [51] and encounter problems with reduced physical fitness and obesity [52]. Lack of interest or motivation to exercise may make it difficult for them to comply with daily physical activity recommendations [53]. The use of virtual reality electronic games that combine physical activity and play, known as exergames or active video games, has been found to be an effective intervention to increase cognitive capabilities and to enhance body movement and energy expenditure in healthy individuals [20,54-57].

Several studies have found the use of exergames to have beneficial effects on cognitive performance in children with ASD. Anderson-Hanley et al. [58] found an improvement in behavioral and cognitive performance, specifically a decrease in repetitive behavior and an increase in EF, after participation in an exergame intervention called *Dance Dance Revolution* by 12 school-aged children with ASD. Similarly, Hilton et al. [45] examining earlier pilot data from the current study, found an improvement in the EF areas of working memory and metacognition, the motor areas of strength and agility, and response speed, in children with ASD following participation in the Makoto arena, an exergaming intervention. These findings suggest that the use of exergaming has the potential to be an effective intervention tool to improve EF and motor functioning in children with ASD.

Other studies investigating the use of exergames as intervention tools in children with other conditions have found positive results as well. A study investigating the effects of Wii interactive games on sensorimotor function in children with Down syndrome found an improvement in motor proficiency, visual integration skills, and sensory integrative functions [59]. In addition, Sandlund et al. [60] found an increase in physical activity participation and motor performance in children with cerebral palsy following a PlayStation2 exergame. These findings provide evidence to suggest that motion-interactive videogames may help to improve functioning in children with various conditions and could lead to an enhanced quality of life. However, review of literature done by Best [61] identified only 2 studies in typically developing youth [20,62] and one study in children with developmental disorders [58] that examined the utility of exergaming in improving cognitive function in youth; further research is needed to study the short and long-term influences of exergaming on cognition, specifically EF, in children.

This study aimed to investigate whether EF, motor skills, and response speed in children and adolescents with ASD, aged 8 to 18 years of age, would be positively affected by participating in 30 or more Makoto arena sessions. Developed as a motor response speed game, the Makoto training arena was initially used in sports, schools, and medical rehabilitation to improve response speed, attention and physical fitness of participants (Makoto, USA, Inc., n.d.). [63]. The Makoto arena consists of three 6-foot tall towers, spaced 6 feet apart in a triangular configuration. Each of the three towers has 10 lights, which illuminate with an associated tone in random order. Lower tones signify that the illuminated light is near the bottom of a tower, while higher tones indicate a location near the top. Different speed progressions and games are offered, with the goal of being able to identify and tap the light as rapidly as possible before the allocated time expires. Measuring overall accuracy and response speed, the Makoto device also provides instant auditory reinforcement.

The current study combines novel data with data collected from our previous pilot study [45] to address the following research questions: 1) Does participation in the Makoto arena as an OT intervention improve EF among school-aged, high-functioning children on the autism spectrum? 2) Does participation in the Makoto arena intervention positively affect motor skills and performance among school-aged, high-functioning children on the autism spectrum? and 3) Does participation in the Makoto arena result in improved response speeds among school-aged, high-functioning children on the autism spectrum?

**Method**

**Research design**

Using a repeated-measures study, we compared pre-intervention assessments with post-intervention assessments to determine whether these outcomes were affected by the Makoto arena intervention. IRB approval was obtained prior to data collection.
Participants

Study participants were high functioning children and adolescents with ASD, between the ages of 8 and 18 years, who were recruited from two schools that provided services for children and adolescents with ASD. One school was a public school and the other was private. In comparing the students who went to the private school versus the public school, no demographic or socioeconomic differences were observed. Additional study participants were recruited through a parent network comprised of families having children with ASD in the St. Louis, MO, greater metropolitan area. Inclusion criteria were having been diagnosed with ASD, an IQ score of 65 or higher, and a willingness on the part of the child to participate in the Makoto intervention for approximately 3 times per week. Students with IQs lower than 65 were excluded from the study. Our concern was that students with IQs lower than 65 might serve as potential confounders of the study outcome of EF. For students without available IQ scores, researchers administered the Wechsler Abbreviated Scale of Intelligence [64]. Additional exclusion criteria included students with sensory impairments or behavioral problems who would be unable to see or hear the cues provided by the Makoto arena intervention, or those children and adolescents who were unable or unwilling to follow the directions of the researchers. The ASD diagnosis of study participants was made by an experienced clinician following the criteria of the fourth edition, text revision, of the DSM [65].

Measures

Study participants were evaluated before and after intervention with the Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition (BOT–2) [66] and the Behavior Rating Inventory of Executive Function [67]. During each Makoto arena session, the average reaction speed of each study participant was recorded.

The Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition (BOT–2) [66] was used to assess motor proficiency, which includes fine motor coordination and integration, manual coordination (manual dexterity and upper extremity coordination), bilateral body coordination and balance, and strength and agility. Gender- and age-specific standard subscale scores are generated, as is a total motor composite score, which have been normed for participants between ages 4 and 21 years. For this study, all BOT–2 assessments interrater reliability at the item level was >90% before scoring the assessments. Greater motor performance is correlated with higher scores on the BOT–2. The BOT–2 has strong internal subset consistency (0.71–0.95), internal composite consistency (0.93–0.97), test– retest reliability (0.48–0.94), and interrater reliability (0.92–0.99) [66]. Good content and construct validity have been established for this instrument.

The BRIEF [67] was used to assess the behavioral and cognitive characteristics of EF with a standardized 86-item, parent-report questionnaire. Higher BRIEF scores indicate greater EF impairment and the instrument is standardized for age and gender. BRIEF t-scores of greater than 65 indicate executive impairments. The BRIEF is comprised of two indices, behavioral regulation (modulations of emotions and behavior) and metacognition (ability to initiate, plan, organize, and sustain future-oriented problem solving in working memory), and one global executive composite summary score. Internal consistency of the BRIEF is strong (0.82–0.98) as is test–retest reliability (0.72–0.83) [67]. Content and construct validity for this assessment are good and moderate inter-rater reliability (overall mean r = 0.32) have been established.

Behavioral regulation components of the BRIEF include inhibit (not acting on impulse), shift (transferring without difficulty from one situation to another), and emotional control (ability to temper emotional reactions). Components of metacognition include initiate (beginning a task or generating ideas), working memory (ability to hold information in memory for task completion), plan/organize (ability to balance and handle different task demands), organization of materials (orderliness of spaces in which the child works and plays), and monitor (observe and adjust on-task habits).

The Makoto arena provides average response time and accuracy information for each session played. Accuracy measures the percentage of times the participant hits the target within the time limit set by the speed level. Before each speed level increase, the participant needed to attain at least 95% accuracy.

Participants were also asked a group of questions after completing the protocol indicating how much they enjoyed participating in the game, if they thought it helped them get better at other things, and if they were glad to have participated in the study. Answer choices were a Likert scale (1 = not at all, 2 = a little, 3 = somewhat/sort of, 4 = pretty much, 5 = very much).

Intervention

Participants were allowed choices on the frequency of the intervention. They usually completed up to three 2-minute Makoto arena sessions in a row each day with rest periods between, and up to 6 sessions per week, with a total average duration of 8 weeks, with a range of 6 to 10 weeks, to complete the 30 sessions. Response speed was generated from approximately 1,800 attempts to hit the Makoto arena targets during the 30 sessions. We began each participant at the slowest speed and we increased to the next faster speed each time they mastered the previous speed level by at least 95%. The levels were set at: 3 seconds (s), 2.5 s, 2.25 s, 2.0 s, 1.75 s, 1.5 s, 1.3 s, 1.17 s, 1.04 s, 1.0 s, and 0.95 s.

Procedures

After training, graduate students or the principle investigator administered the assessments and interventions in quiet rooms with limited distractions at the Clayton Child Center, Edgewood Center, and Washington University School of Medicine in St. Louis, Missouri. We conducted the interventions within one month of pretesting for each child and we completed post-testing within one month of completion of the intervention. To assure safety, participants were required to wear stable shoes, such as athletic shoes, while engaging in the Makoto arena. All participants were either at a school with a school nurse available or accompanied by a parent in case they might be injured during participation in the game.

Statistical analyses

The IBM SPSS Statistics 20 (IBM Corporation, Armonk, NY) was used for data analysis. Nonparametric measures were used to analyze the BRIEF and BOT–2 data because of the small sample size and skewed distributions in two of the motor variables. We compared standardized scores with test norms and examined Spearman rho correlation coefficients between EF and motor subscale standardized scores for pretests. Standardized scores for pre- and post-tests were compared and analyzed by using paired Wilcoxon signed rank tests to detect significant effects related to the intervention. We analyzed reaction speeds between Sessions 6 and 30, allowing five practice trials for each child before scores were included in the analyses, using paired Wilcoxon signed rank tests to determine significant changes. Additionally, we calculated standardized effect sizes using standard approaches (0.10–0.24 = small, 0.25–0.39 = medium, >0.40 = large; [68,69] for the pretest–posttest scores. Effect size calculations for non-parametric data analyses followed the method used by Weberg, Hjermstad, Hilmarsen, and Oldervoll [70]. The p value for significance was set at p < 0.05.

Results

Recruitment produced 18 participants with ASD for study enrollment. One child was discontinued from the study because he would not follow the Makoto study protocol and baseline data collection was not possible to complete. The remaining 17 participants completed the protocol. Four of the parents did not return the BRIEF post-test forms so those were not included in the analyses. Participants were between 8 and 18 years of age (mean = 11.76) at the time intervention began with 12 males and 5 females. Participants had occasional falls while engaged in the intervention, but none involved any sustained injuries. Full-scale IQs ranged from 66 to 136 (mean = 113).
behavioral regulation reported (3). Among the many potential target communities, 
aging adults (4), low income (2), middle income (5), high income (6), 
and obesity experienced by this population (51-53). To help deal with common
problems of weight gain from medications and reduced physical fitness
in motivating children and adolescents with ASD to comply with
participation in this type of formal physical activity may be helpful
typically developing children, in a prior study (49). This suggests that
exergame qualifies it as being a formal activity. Formal activities showed
more diverse participation among children with ASD, more similar to
typically developing children, in a prior study (49). This suggests that
participation in this type of formal physical activity may be helpful
in motivating children and adolescents with ASD to comply with
daily physical activity recommendations to help deal with common
problems of weight gain from medications and reduced physical fitness
in obesity experienced by this population (51-53).

Discussion

Findings from this study corroborate previous studies, which
found motor impairment (11,14-18) and EF impairment (12,13) in
children with ASD. They also suggest that the relationship between
motor performance and EF observed in typically developing children (36-40)
and those with intellectual disability (41) may also exist in children with ASD.

Improvements seen in this study in reaction speed, EF, and motor
performance after participation in the Makoto arena intervention
support previous findings from use of the Makoto arena (45). They
also support previous studies that found physical exercise to improve
cognitive processes in children and adolescents with ASD (46,47).
Significant improvement in EF in the entire section of metacognition,
beyond the single subtest of working memory, strengthens and expands
previous findings from Hilton et al. (45). These changes may arise from
increased cerebral blood flow, which leads to an improvement in
the delivery of oxygen and nutrients to the brain (43,48). Changes
may also be attributed to generalization of skills learned through the
intervention. For example, the game requires cognitive flexibility and
inhibition of prepotent responses in order to respond to new stimuli.
These learned skills may generalize beyond the game context, as
captured by improvements on the BRIEF. The repeated demands of
rigorously moving their whole bodies to increase speed in hitting the
targets is likely the reason for improvement in strength and agility as
captured by improvements in the BOT-2. The participants' reports of
improvements in other areas of their lives suggest the possibility of
more generalizable improvement effects.

The fact that all of the qualified participants who began the study
and were willing to follow the protocol did complete the entire sequence of
the intervention indicates their willingness to participate in this type of
substantial physical activity. Interest and motivation to participate
seemed to carry them to completion of the protocol, even though some
reported not enjoying it. The formal structure of the protocol of this
exergame qualifies it as being a formal activity. Formal activities showed
more diverse participation among children with ASD, more similar to
typically developing children, in a prior study (49). This suggests that
participation in this type of formal physical activity may be helpful
in motivating children and adolescents with ASD to comply with
daily physical activity recommendations to help deal with common
problems of weight gain from medications and reduced physical fitness
and obesity experienced by this population (51-53).

Table 1: Executive Function and Motor Impairments of Participants

<table>
<thead>
<tr>
<th>Category</th>
<th>% Percent Impaired Pre</th>
<th>% Percent Impaired Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRIEF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavior Regulation Index</td>
<td>71</td>
<td>54</td>
</tr>
<tr>
<td>Metacognition Index</td>
<td>71</td>
<td>62</td>
</tr>
<tr>
<td>Global Executive Composite</td>
<td>71</td>
<td>46</td>
</tr>
<tr>
<td>BOT2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine Manual Control</td>
<td>53</td>
<td>59</td>
</tr>
<tr>
<td>Manual Coordination</td>
<td>65</td>
<td>59</td>
</tr>
<tr>
<td>Body Coordination</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>Strength &amp; Agility</td>
<td>65</td>
<td>42</td>
</tr>
<tr>
<td>Total Motor Composite</td>
<td>76</td>
<td>59</td>
</tr>
</tbody>
</table>

*Percent Impaired indicates % of participants with a score considered to have potential clinical significance (t score >65 for BRIEF, t score < 40 for BOT-2).

Table 2: Pre & Post Intervention Executive Function Scores (n = 13)

<table>
<thead>
<tr>
<th>Test</th>
<th>Median Pre</th>
<th>Median Post</th>
<th>Z-score</th>
<th>Effect size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavioral Regulation Index</td>
<td>77.46</td>
<td>69.78</td>
<td>-1.51</td>
<td>0.50</td>
</tr>
<tr>
<td>Metacognition Index</td>
<td>72.66**</td>
<td>66.23</td>
<td>-2.81</td>
<td>0.55</td>
</tr>
<tr>
<td>Global Executive Composite</td>
<td>75.89</td>
<td>65.45*</td>
<td>-2.40</td>
<td>0.47</td>
</tr>
</tbody>
</table>

* p < 0.05, **p < 0.01. BOT2: Bruininks-Oseretsky Test of Motor Proficiency-Second Edition, BRIEF: Behavior Rating Inventory of Executive Function.

Table 3: Pre & Post Intervention Motor Scores (n = 17)

<table>
<thead>
<tr>
<th>Test</th>
<th>Median Pre</th>
<th>Median Post</th>
<th>Z-score</th>
<th>Effect Size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOT2 Standard Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine Manual Control</td>
<td>39.30</td>
<td>38.28</td>
<td>-0.88</td>
<td>0.00</td>
</tr>
<tr>
<td>Manual Coordination</td>
<td>34.30</td>
<td>39.16</td>
<td>-1.72</td>
<td>0.29</td>
</tr>
<tr>
<td>Body Coordination</td>
<td>36.30</td>
<td>40.16</td>
<td>-0.67</td>
<td>0.15</td>
</tr>
<tr>
<td>Strength and Agility</td>
<td>38.40</td>
<td>40.16</td>
<td>-3.17</td>
<td>0.54</td>
</tr>
<tr>
<td>Makoto Response Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Session 6 &amp; Session 30</td>
<td>1.46</td>
<td>1.18**</td>
<td>-3.62</td>
<td>-0.62</td>
</tr>
</tbody>
</table>

* p < 0.05, **p < 0.01. BOT2: Bruininks-Oseretsky Test of Motor Proficiency-Second Edition, BRIEF: Behavior Rating Inventory of Executive Function.
This study is limited by its small sample size and lack of a randomized control group. Lack of a control group does not allow for comparison of the experimental group to the improvements that might be seen through normal development and familiarity with the assessments, although each test is standardized for age and gender. In addition, use of subjects as their own controls in a repeated measures study such as this one has potential merit as a small n study in the rehabilitation field [71]. Portney and Watkins [72] indicate the major advantage of this design as “the ability to control for the potential influence of individual differences.” The range in length of time to complete the intervention was also a limitation, since it varied as much as two months among participants. Another limitation of this study is that this particular exergame is expensive for individual families and is best used in a school, therapy center or community recreation center. Scientific rigor could be increased by adding a randomized controlled trial with a larger cohort and including an observation-based measure of EF. Adding a measure to examine maintenance of improvements would also add to the value of these findings and strengthen their generalizability. Additional research should be conducted to replicate and extend these findings, to examine dosage and alternative exergames, to clarify exergaming components that may influence cognitive and motor outcomes, and to examine the long-term sustainability of exergaming for ASD. Additional work is also needed to examine the effects on children who are not defined as high functioning, who might, indeed, benefit from this type of intervention.

Conclusion

It is important to identify effective, interesting, and motivating interventions to be able to provide the optimal impact through therapy for children and adolescents with ASD. The findings from this study suggest that the use of exergaming, specifically the Makoto arena, may be useful for improving EF and motor skills in children and adolescents with ASD, although further examination of dosage, alternative exergames, long-term effects, and specific effects on school performance are warranted. Significant correlations between certain EF and motor scores suggest a relationship between the two constructs. Continued work addressing this line of inquiry to further understand and possibly increase the benefits of various types of exergaming for people with ASD will be helpful to inform best practice.

Acknowledgements

This study was partially funded by Washington University School of Medicine, Program in Occupational Therapy. The authors would like to thank the participants and their families, the Clayton Child Center, and the education director, Kelly McCrary, the teachers and the staff at Edgewood Children’s Center. They would also like to thank Shannon Gaetke, Sarah Dugar, Alisha Munoz, Ben Och, Kristin Seefeldt, Caitlin Stockelman, Stephanie Zaepfel, Amanda Arter, Kristina Cumpata, Lisa Colton, Sarah DobbS, Hailey Johnson, Jill Phillips, Kelly Schwieterman, Sophie Goloff, Andrea Bennett, Ashlyn Hudson and Danielle Vest for their help with testing, scoring, and data entry.

References
