The Effects of Rock Climbing on Functional Strength, Spatial Reasoning, and Executive Function in Children with Autism

Julia Taylor

7 May 2017

Exercise Science

Ohio Dominican University

Approved By

, Advisor

, Reader

Accepted By

, Director, ODU Honors Program
Abstract

Indoor and recreational rock climbing has become an increasingly popular sport among children and adults. Additionally, recent research has demonstrated that active therapy, such as swimming and hippotherapy, is beneficial for children with autism. PURPOSE: To determine the effects of six weeks of rock-climbing on functional strength, spatial reasoning, and executive function for children with autism. METHODS: Seven subjects (8-14 years old, all male) completed six weeks of rock climbing at a pre-established gym. Examinations of Cognitive Trail Making Tests (CTMT) and hand grip strength were completed for all participants prior to the start of classes and after six weeks of training. For hand grip strength, three trials were completed on each hand using a standard hand grip dynamometer. The two highest results were taken and added to represent total grip strength. The CTMT was performed via directions given through the standard protocol. RESULTS: The data did not reveal any significant differences; however, there were positive trends among all variables. CONCLUSION: The research was limited by the number of subjects and variability between subjects. Even so, the positive trends suggest that more research may show significant benefits from rock-climbing. Past research evaluating adventure education, psychological benefits of rock climbing, and neurological and physiological adaptations to exercise still support the possibility of rock climbing as a viable therapy option. With continued research in rock climbing, we hope to be able to implement a different, potentially more beneficial, therapeutic modality that addresses cognitive and physical impairments commonly observed in children with autism.
Introduction

From the first case studies on children with autism, there has been an increase in research conducted in order to better understand autism (Kanner et al, 1938; Bryson et al, 2007). At its most basic level, autism is a neurocognitive disorder affecting social behavior. Signs for the disorder are usually noticeable before the child reaches three years of age (Kanner et al, 1943). These signs include difficulty in verbal and nonverbal communication, a lack in desire for social interaction, and possible repetitive and or obsessive behaviors (NCCWCH, 2011; Ozonoff et al, 2016; America Psychiatric Association, 2013). More recent discoveries show most cases of autism have strong aversions to certain sensory experiences (Baranek et al, 2007; American Psychiatric Association, 2013). Each patient may display a different combination of symptoms and at a different level of severity, placing them somewhere along the spectrum for Autism Spectrum Disorder (NCCWCH, 2011; Faroy et al, 2016; American Psychiatric Association, 2013). The symptoms displayed may change with time or conditions-- some may improve with treatment, while some patients may develop new symptoms or their current ones may worsen as a result of changes in environment or increasing severity of the disorder (Kanner et al, 1943; London EA, 2011; American Psychiatric Association, 2013).

Autism spectrum disorder (ASD) can be difficult to diagnose and treat because it overlaps and or co-occurs with multiple other disorders such as Attention Deficit Hyperactivity Disorder (ADHD), Mitochondrial Dysfunction Disorder, Rhett’s Disorder, Fragile X Syndrome, Epilepsy, and anxiety disorders (Ko, 2016; Grzadzinski, 2016). Because of this it can be difficult to pinpoint what medicines, therapies, and treatments will have a lasting effect for all people with autism. While there are no certain causes or cures for autism, there is strong scientific evidence that it is a combination of genetic and environmental factors and that various forms of
therapy effectively improve the daily living standards of individuals with autism (Faroy, 2016; London EA, 2011).

Children with autism are usually at least a year to two years behind their typically developing peers in regards to strength and motor skills, which restricts them from being able to partake in the same activities (Hannant et al, 2016). These limitations begin early in childhood, around 2-3 years of age or earlier, and become worse if they are not addressed (Hannant et al, 2016; McDonald et al, 2014; Kanner et al, 1943). According to recent research, greater deficiencies in motor skill development are detrimental developmental delays which lead to more severe cases of autism (McDonald et al, 2014). Furthermore, research has shown that early intervention is key to accelerated results because the brain is still developing neural pathways, allowing for greater neural plasticity (Rogers et al, 1996). Brain development continues until adulthood, usually into the early to mid-twenties, so adolescents and young adults may also see results from intervention therapies (Pujol et al, 1993). If early intervention occurs, they may experience neurological adaptations in as little as six weeks. Increases in strength between 6-12 weeks occur because of these neurological adaptations (Gabriel et al, 2006). At this time, neurons have learned when and how much to contract as well as how to synchronize muscle contraction for increased coordination (Semmler, 2002; Gabriel et al, 2006). Moreover, at the initial learning of a motor task the body will feel unstable and co-contraction will occur; thereby, inhibiting the full recruitment of the muscle for the attempted task (Sale, 1988). As long as intervention lasts at least 6 weeks, these neurological developments should be seen and should improve motor skill development. Growth in strength and motor skill coordination at a young age will help children struggling with autism to be more comfortable alongside their peers and more likely to engage socially (MacDonald et al, 2016).
Previous research using aquatic and equine therapy has shown that sports and physical activities can be an effective means for helping children with autism to develop physically, socially, and cognitively (Amoros et al, 2014; Borgi et al, 2016). Moreover, aquatic and equine therapies are useful in countering preventative diseases such as obesity, which has been reported to be prevalent in 42.2% of children with autism (Lawson et al, 2016; Tyler et al, 2015). While aquatic and equine therapies have been useful in the past, indoor rock-climbing could have greater potential because it offers a larger combination of benefits. Rock-climbing requires a significant amount of strength in the upper limbs, lower limbs, and core (Morrison et al, 2007; Deyhle et al, 2015; Watts et al, 2004). Additionally, rock-climbing requires muscles associated with both fine and gross motor movements to be used in unison and in alteration; requiring great motor control. Research on the relationship between physical activity and neural development has shown that exercise increases the growth of new neurons, especially in the hippocampus, and promotes effortful learning in animals (Shors, 2014). The hippocampus is important for this particular group of subjects because it plays a key role in recognizing and producing emotion; children with autism often appear either emotionless or have bursts of unexplained rage or excitement and are known for having difficulty in reading other’s emotional states (Iidaka et al, 2003; American Psychiatric Association, 2003; Kanner et al, 1943). So, increasing the neural development in the hippocampus may allow for more stable and consistent emotional responses. Effortful learning is becoming increasingly important because it integrates the new neural cells into the network; thus, preventing them from dying away like many cells do (Shors, 2014). Because of the effects of the effortful learning which occurs in newly learned skills such as rock-climbing, there should be new, long-lasting neurons (Shors, 2014). Cognitive function is also engaged as rock-climbing involves the planning and plotting out of routes, meaning climbers
must solve “puzzles” in order to finish routes. There are often multiple ways to climb routes which means there is an option for creativity and decision-making, allowing for the use of executive function (Kamijo et al, 2010). Spatial awareness and reasoning is another cognitive ability which is necessary for climbing. Finally, in gym settings, climbers are typically placed in a group environment with trained professionals where they are encouraged to engage verbally with coaches, socially with fellow climbers, and allowed time to take breaks when feeling over-stimulated. Each of these elements of rock-climbing make it a valuable therapy option for children with autism; however, there has been little research to support this specific study. Thus, we hypothesize that evaluating the strength and motor skills in children with autism in addition to testing their spatial reasoning and executive functioning before and after rock climbing will help to determine if rock-climbing is an effective means of therapy.

**Methods**

**Subjects** Children with autism between the ages of 8-18 years old were recruited. No gender specifications were necessary. Subjects had various diagnoses of autism, but most were considered high-functioning. All subjects needed to be self-reported as moderately active previous to the trials. Subjects’ names were given a number to keep their identity anonymous.

**Assent and Consent** Each parent or guardian of the subjects was given an informed consent form, an informational sheet, and was allowed to ask questions about any portion of the experiment. Each child was required to give a verbal or nonverbal assent before beginning the experiment. They were permitted to leave the study or be removed from the study at any time, if the parent or child asked.

**Experimental Design** The study was a six week longitudinal design, including one climbing session per week for an hour and a half each session. During each class, the subjects warmed up
for 5-10 minutes with climbing either by traversing (climbing laterally) or by climbing vertical routes. The subjects then stretched together for approximately 5 minutes. After stretching, the subjects were taught a short climbing lesson which included pre-established lessons such as “quiet feet,” “long arms,” “resting positions,” and “following routes.” Then, the subjects returned to climbing and attempted to practice lessons of the day as well as work on “problems.” Problem routes were those which climbers were able to complete but were challenging enough that they had to practice multiple times in order to accomplish them. Climbers could take anywhere from several attempts to several practices to solve their problem route and often had to try different methods, techniques, and patterns of climbing. Routes were pre-graded and color coordinated either by hold color or by tape color, as seen in the picture. All climbers completed bouldering routes (without ropes) between levels V1-V4 and top rope routes between grades 5.5-5.8. The rating system for routes was pre-existing. The dependent variables included measures of spatial reasoning, executive function, and grip strength. Each subject was assessed one time before the climbing sessions began and one time after the 6-week session concluded.

**Grip Strength** A commercially available hand grip strength dynamometer was used to calculate the subjects’ strength. Again, three trials were performed for each subject. The subjects were shown how hold the hand grip dynamometer with their second IP joint resting on the handle and
placing it next to their side (removing wrist flexion and/or extension), pointing down. All were directed to hold it the same way. The handle was adjusted to the appropriate size for each subject. Then they were asked to squeeze the hand grip device as hard as they could for 3 seconds. The number on the device was then recorded and they were asked to repeat the process two more times. The highest value from each hand was taken and added together to find total hand grip strength.

**Cognitive Function** Subjects completed the Comprehensive Trail-Making Test (CTMT), which was shown to be an effective means for measuring spatial reasoning and executive function (Bowie et al, 2006). Briefly, the examinee drew a line to connect the numbers 1 through 25 in order. Each numeral was contained in a plain circle. Depending on the trail, there were also circles with nothing written or drawn inside them and circles with distracting patterns in them; these were to be avoided by the examinee but were intended to distract him from the circles with numbers in them. The first trail did not have distractor circles on it. For the second trail, the examinee again drew a line to connect the numbers 1 through 25 in order. This time, there were twenty-nine empty distractor circles on the same page. For the third trail, the examinee again drew a line to connect the numbers 1 through 25 in order; this time attempting to avoid touching the 13 empty distractor circles and 19 distractor circles containing drawings and patterns. On the fourth trail, the examinee drew a line to connect the numbers 1 through 20 in order. Eleven of the numbers were presented as Arabic numerals, (e.g., 1, 7); nine numbers were spelled out (e.g.,
Ten, Four). During the final trial, the examinee drew a line to connect in alternating sequence the numbers 1 through 13 and the letters A through L. The examinee began with 1 and then drew a line to A, then proceeded to 2, then B, and so on until all the numbers and letters were connected. Fifteen empty distractor circles appeared on the same page. Each trail was timed with the same stopwatch each time. The test took between 5-12 minutes to complete and only about 5 minutes to score. It was completed before the first climbing session and then again after the last climbing session. The scoring was based from guidelines in the examiner’s manual. First, the subject’s raw score in seconds from each trail was converted to the standardized score from the tables in the back of the manual. Because the first three tests were of similar concept and all subjects were able to complete them at least once, they were added together to form CTMT F3 score and the average of the three was taken to make them comparable. If a subject was unable to complete trails 2 or 3 (because of time constraints) then he was given an ‘18’ because this was the lowest normalized score in the manual and included all those finishing over a certain time. The fourth and fifth trails were combined because they were both complex trails and the average of the two was taken to create a comparable score. This scoring was per the direction of the examiner’s manual. Similarly, the raw time in seconds from each trail was converted to a standardized value from the back of the manual. The standardized scores allowed for a better view of each subject’s performance based on age, rather than simply time. Both categories—CTMT F3 and CTMT L2—were categorized by the CTMT descriptive traits (severely impaired, mild to moderately impaired, below average, average, high average, superior, very superior) which were converted to numeric values (1-7) for statistical evaluation. The number of trails completed (# CTMT completed) was also included as a point of evaluation because some subjects varied in the
number of trails they could finish. An example of the test is in the picture below. The subject was on trail 2 in this image.

**Statistical Analysis** Each of the following categories were tested for significant difference between pre and post: hand grip strength, number of CTMT completed, CTMT F3 score, CTMT L2 score, and CTMT Descriptive. Additionally, the percentage of change from pre to post values was found for all variables. The standard deviation between subjects for all pre-values and for percentage of change was also found.
Table 1: On this table, it can be seen that all variables increased in regards to average percent change; though, not for all subjects. Some subjects, such as subjects 1, 5, and 6 decreased in hand grip strength performance. Only one subject, subject 3, decreased in number of trails completed. The differences in descriptive values for CTMT varied throughout. Calculated standard deviations for the initial values (pre-tests), ending values (post-tests) and for percent change are included at the bottom of the table to show the variation throughout. Although only three subjects were able to complete the last two, complex trails, those who did had a higher percentage of change (though there was also high standard deviation here).
Figure 1: On average, there was a positive change for all categories. Hand-grip, CTMT 4 and CTMT 5 had the greatest average percentage of change. These categories also had high standard deviation.

Figure 2: The average hand grip strength post values were greater than the pre values, showing an increase in average strength for the subjects after climbing for six weeks.
Figure 3: On average, the subjects increased the number of trails they were able to complete for the CTMT after the six weeks of climbing class.

Figure 4: T score is standardized score with a mean of 50 and a standard deviation of 10. Average T scores for the first three and last two trails for pre and post trials. There were significant differences from pre to post, but of the three who completed the last two trails, two improved and one stayed the same. The subjects stayed about the same on the first three trails.
Figure 5: The average descriptive explanations for all subjects’ performance on the CTMT remained the same. On average, subjects did not move from one category (such as severely impaired) to another (such as mild to moderately impaired) within the six weeks of climbing classes.

**Discussion**

Although there were no significant differences in any of the variables, there was a positive trend in percent change for each category (Figure 1). This positive trend denotes that there was some amount of improvement in all categories for all or most of the subjects, although, again no significant differences were found for any variable. Figure 4 is important because it shows that there were no apparent decrements in ability as a result of climbing and in those who were able to complete the last trails, their performance improved over the six weeks. This may show that rock climbing has an influence on more complex tasks rather than simple. Additionally, the fact that some subjects were able to complete the last two trails indicates that the CTMT was not too difficult or impossible for this special population and that it may be used for evaluation of their performance. These results can be used to further the experiment with
more control over variables in the future. For example, because of the low recruitment numbers, variability remained high. This could be due in part to the range in age—between 8 to 14 years old—as there is the possibility of puberty, differences in musculature and development, and overall difference of motor coordination with age.

**Implications** While this study explores the effectiveness of rock climbing as a modality for increasing problem-solving capabilities, functional movement, and cognitive control, rock climbing could also be considered for use in the classroom for psychological development and for sociability. As rock climbing classes parallel the typical learning environment in that both include physical structure, schedules, and task organization; it is likely that subjects would experience an increase in motor skills as well as task proficiency as was seen in similar studies (Pan et al, 2016; Schultheis, 2000). Notably, these studies also show that physical intervention has a lasting effect on children with autism—specifically, the motor skills did not degrade 12 weeks post-intervention (Pan et al, 2016). The research from Pan et al., is interesting in regards to our research because of the layout of the climbing class. Each week, subjects warm-up, stretch, learn a lesson, and then practice using what they have learned. This forms the routine, structure, and task organization that these children need. By climbing on the rock walls and attempting to “solve problems” by figuring out how to finish the routes and finding which holds are part of their route, they are learning motor skill coordination and increasing cognitive function at the same time. Additionally, it is suggested that children with autism may have social impairments because of defective neurogenesis in the amygdala—which is engaged in social interactions and new environments or experiences (Mercandante, 2008). However, the fact that the effects of the 12-week therapy from Pan-- which involved a new environment and task
completion--lasted on the children says that active therapy may be the key to neurogenesis in the amygdala (Pan et al, 2016).

There has been an increase in outdoor and recreational education for all types of students because of the increased interest in these types of activities as well as the psychological benefits they provide (Attarian, 1989; Hyder, 1999; Cross, 2002). It is known that children with autism typically struggle with verbal and nonverbal communication and often lack the desire for social interaction (American Psychiatric Association, 2013; Kanner, 2005). Additionally, delays in motor skill developments may be one cause for social discomfort in children with autism (MacDonald et al, 2014; Hannant et al, 2016). Rock climbing may be an effective modality for aiding in this motor development, as our research shows that, on average, subjects increased hand grip strength between pre and post trials [Figure 2]. Studies focused on the use of outdoor education for the purpose decreasing perception of alienation and increasing personal control among at-risk adolescents found that rock climbing did in fact aid in personal control and feeling of inclusiveness (Cross, 2002). Traits such as these would aid in psychological development and social interaction for children with autism. In another study, outdoor adventures such as rock climbing and rappelling were part of a learning program to increase self-esteem, cooperation, compassion, interdependence, increase accountability and responsibility, and healthful risk-taking (Chase, 1981). Successes in the program showed increased self-confidence and creative responses to fear (Chase, 1981). Increased self-esteem and ability to handle scary situations would help a child with autism in social developments because he would be less afraid of his peers and more confident in his ability to engage socially. One could also argue that improvement in problem-solving abilities would similarly help to increase self-esteem. Some of the subjects in our study experienced increases in the number of trails they could complete and a
decrease in the amount of time it took them to complete the trails [Figure 3 and 4]. Though these improvements were not statistically significant, it is considerable that the subjects may have also experienced psychological benefits either along with or as a result of possible improvements in executive function and spatial reasoning. Another study attempting to support the idea that adventure education promotes positive psychological development did find an increase in overall hardiness for the subjects; though other variables could not be verified because of small sample sizes (Sheard et al, 2006). Studies surrounding adventure education discuss the psychological and social elements which make these lessons positive experiences; however, the initial development of these programs came about as a way to encourage physical activity in a safe and more exciting way (Attarian, 1989; Hyder, 1999; Cross, 2002). Our research sought to discover if children with autism could be benefited by a therapeutic modality of rock climbing based on a class-like setting, and the positive trends found in all variables [Figure 1] suggest that it may be so, but that more research is needed. Based on this scientific evidence, incorporating recreational climbing into the school system holds a variety of potential benefits which should be considered (Attarian, 1989; Hyder, 1999).

**Limitations and Future Considerations** To avoid the high variability found in this study, subsequent studies could recruit subjects with closer pre values in handgrip and CTMT time. By doing so, we would ensure that the end result was not skewed by differences in initial capabilities. Additionally, having a control group—comprised of children with autism who do not partake in the rock climbing classes—may help us to evaluate the significance of the changes occurring in children who do attend class compared to those who do not. Increasing the number of subjects involved would also increase power and thus increase the possibility of finding a significant difference. The time-span may also need to be adjusted. Hypertrophy can be seen in
as little as six weeks, but this is more likely in untrained individuals. Depending on the set of subjects recruited, the time span could be adjusted longer for those who are trained and shorter for those who are not. Additionally, while neurological adaptations occur within 6-12 weeks, neurogenesis takes a much longer amount of time. This means that though muscle coordination and muscle efficiency can increase in those weeks, new neural pathways may take a much longer time to form, requiring longer intervention. Similar to other studies, it may also be beneficial to test the subjects several weeks after intervention has concluded to see if the results are lasting.

With additional research we can effectively determine if rock climbing is an effective modality for cognitive and functional movement. Likewise, future studies might also support rock climbing as an effective method for increasing sociability and communicativeness.
References


