Acute Bouts of Assisted Cycling Improves Cognitive and Upper Extremity Movement Functions in Adolescents With Down Syndrome

Shannon D. R. Ringenbach, Andrew R. Albert, Chih-Chia (JJ) Chen, and Jay L. Alberts

Abstract
The aim of this study was to examine the effectiveness of 2 modes of exercise on cognitive and upper extremity movement functioning in adolescents with Down syndrome (DS). Nine participants randomly completed 3 interventions over 3 consecutive weeks. The interventions were: (a) voluntary cycling (VC), in which participants cycled at their self-selected pedaling rate; (b) assisted cycling (AC), in which the participants’ voluntary pedaling rates were augmented with a motor to ensure the maintenance of 80 rpm; and (c) no cycling (NC), in which the participants sat and listened to music. Manual dexterity improved after AC, but not after VC or NC. Measures of cognitive function, including reaction time and cognitive planning, also improved after AC, but not after the other interventions. Future research will try to uncover the mechanisms involved in the behavioral improvements found after an acute bout of assisted cycling in adolescents with DS.

Key Words: exercise; intellectual disability; cycling; Down syndrome; young adults; physical activity; executive function

Down syndrome (DS) is one of the most prevalent conditions associated with intellectual disability (ID), affecting one in every 733 live births in the United States. Declines in cognitive functioning in individuals with DS can increase the risk of Alzheimer’s disease (Zigman & Lott, 2007) and compromise performance of activities of daily living (ADL). People with DS have deficits in cognitive functioning compared with their peers with similar chronological ages (Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010; Rowe, Lavender, & Turk, 2006). Adolescents with DS have been shown to have diminished levels on cognitive functioning related to working memory, inhibition, planning, and set shifting compared to typical developing adolescents (Lanfranchi et al., 2010). Furthermore, limited cognitive functioning affects their access and participation in formal physical activity programs (Cowley et al., 2010; Rihtman et al., 2010).

In addition to broad cognitive function impairment, individuals with DS have physical characteristics that limit their ability to perform functional ADLs (e.g., toothbrushing, grooming, etc.; Dolva, Caster, & Lilja, 2004). Current exercise interventions for those with DS have not achieved the desired results of improving functional tasks (Andriolo, El Dib, Ramos, Atallah, & da Silva, 2010). In general, the fitness level in children, adolescents, and adults with DS is comparatively low and is thought to stem from motivational (Barr & Shields, 2011) and physiological bases (Fernhall, Tynesson, Millar, & Burkett, 1989; Pitetti, Climente, Campbell, & Barrett, 1992). Specifically, people with DS often chose sedentary activities (Menear, 2007), which they themselves attribute to lack of energy, being too lazy, and the skill being too difficult (Heller, Hsieh, & Rimmer, 2004). Furthermore, congenital heart defects, low muscle tone, obesity (Barr & Shields, 2011), and reduced volume of oxygen (Fernhall et al., 1996), to name a few, contribute to low levels of physical activity in people with DS. Previous studies have examined the effect of exercise on improving physical fitness in people with DS (Giagkoudaki, Dimitros, Kouidi, & Deligiannis, 2010; Mendonca & Pereira, 2010; Mendonca, Pereira, & Fernhall, 2011; Millar, Fernhall, & Burkett, 1993; Millar, Fernhall, Burkett,
& Tymeson, 1998). Some of these studies have shown that an exercise intervention that is adhered to typically results in improved fitness levels for individuals with DS; namely decreased HR variability and HR recovery (Giagkoudaki et al., 2010; Mendonca & Pereira, 2010). However, a recent meta-analysis concluded that the available evidence was inconclusive to demonstrate increased physical outcomes (e.g. VO₂ peak, heart rate [HR] peak, respiratory exchange ratio, and pulmonary ventilation) of aerobic voluntary exercise (VE) in people with DS (Andriolo et al., 2010). Furthermore, few studies have examined the effect of exercise on the upper extremities in people with DS. One study found improvements in upper limb muscle endurance, strength, and function (i.e., grocery shelving task) after a progressive resistance exercise program performed twice a week for 10 weeks for people with DS (Shields, Taylor, & Dodd, 2008). To our knowledge, there is no research on the effect of exercise on manual dexterity in individuals with DS.

Importantly, exercise may be an effective treatment for cognitive function impairments because the positive influence of chronic and acute exercise on cognition has been demonstrated in other populations (e.g., elderly [Colcombe & Kramer, 2003; van Uffelen, Chin, Hopman-Rock, & van Mechelen, 2008]; typical children [Hillman, Erickson, & Kramer, 2008; Hillman, Snook, & Jerome, 2003]; and mice models [Ts65Dn] of DS [Llorens-Martí et al., 2010]). Similarly, there is an emerging body of literature in healthy older adults and individuals with Alzheimer’s disease indicating that exercise results in structural and functional changes in the brain (Colcombe et al., 2004; Kramer et al., 2002; Kramer et al., 2003; Kramer, Erickson, & Colcombe, 2006). These alterations in brain structure and function suggest that central nervous system (CNS) function can be altered via VE in individuals with relatively normal patterns of activation within the motor cortex.

However, because individuals with DS have limited movement output due to physiological (Cioni et al., 1994; Fernhall et al., 1996; Inui, Yamanishi, & Tada, 1995) and psychosocial factors (Jobling & Cuskelly, 2002), their ability to induce changes in CNS function may be compromised when engaging in VE performed at their preferred (i.e., low) rates. When people with DS are asked to voluntarily exercise they do not exercise at the relatively high rate used in animal or human studies, which may explain the previous non-significant therapeutic benefits (i.e., cognitive and upper extremity movement function) of exercise in people with DS. The lack of consistent and substantial improvements in upper extremity movement functioning in people with DS following VE interventions suggest that they may need to have voluntary movement output augmented through mechanical assistance as proposed in our assisted cycling (AC) paradigm.

In the typical population, it has been shown that VE improves physical, cognitive, and health outcomes (Penedo & Dahn, 2005). The limitation for some populations, including those with DS, is the voluntary aspect of the exercise. A recent methodology termed assisted exercise (AE; or forced exercise in animals) has been examined in rodents (Cotman & Engesser-Cesar, 2002; Fisher et al., 2004; Tajiri et al., 2009) and more recently in humans with Parkinson’s disease (PD; Alberts, Linder, Penko, Lowe, & Phillips, 2011; Ridgel, Vitek, & Alberts, 2009), but has not been studied in people with DS. A typical AE paradigm in animals is provided by a motorized treadmill that requires the animal to maintain a running velocity that is greater than its preferred running velocity (Cotman & Berchtold, 2002; Tajiri et al., 2009; Zigmond et al., 2009). Failure to keep pace with the motorized treadmill results in a noxious stimulus (e.g., electric current). It has been demonstrated in animals and most recently in patients with PD that AE, which assisted patients with PD to pedal on a stationary exercise bicycle at a rate at least 35% greater than their preferred voluntary rate, improved clinical function (e.g., motor subscale of Unified Parkinson’s Disease Rating Scale) and upper extremity movement function (e.g., stabilized bimanual dexterity; Ridgel et al., 2009). Recently, non-movement as well as cortical and subcortical changes have been shown post AE in patients with PD (Alberts et al., 2011).

The present study seeks to translate AE data found in animals into an effective and specific exercise for adolescents with DS. We predict that the AC session would exhibit significantly greater improvements in manual dexterity after exercise compared to those in the voluntary cycling (VC) and no cycling (NC) sessions. We predict that the AC and VC sessions, but not NC, will exhibit improved exercise perception after exercise. We predict that the following the AC session, participants will exhibit significantly greater improvements in measures of cognitive function compared
to after VC and NC sessions. Positive results from this project have the potential to change clinical practice or treatment, which may improve movement and cognitive functioning, as well as attitudes towards exercise for adolescents with DS.

**Method**

**Participants**

Nine adolescents with DS who lived with their families completed this study (refer to Table 1 for participant characteristics). Because this study focused on adolescents with DS, participants over the age of 25 were not recruited. Participants were tested for verbal receptive level using the Peabody Picture Vocabulary test (3rd Ed.; PPVT-III, Dunn & Dunn, 1997). Chronological age is a rough marker of adolescence, which is a term in which physical, psychological, and cultural maturation can occur earlier or later than the teenage years (Coleman & Roker, 1998). Because young adults with DS stay in high school into their twenties and because the verbal receptive measure of our participants were on average 6 years and 7 months of age, we will use the term adolescent for our population. In addition, participants were screened for exercise preparedness for health reasons by answering "no" to all seven questions on the Physical Activity Readiness Questionnaire, or received clearance to participate in this exercise intervention study from their physician. Furthermore, any participants with a history of sensory impairment or physical disabilities that would prevent them from completing the exercise intervention were also not tested.

### Table 1

**Participant Characteristics**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Chronological age (years, months)</th>
<th>Mental age (years, months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>25, 6</td>
<td>5, 6</td>
</tr>
<tr>
<td>Male</td>
<td>19, 4</td>
<td>5, 5</td>
</tr>
<tr>
<td>Female</td>
<td>14, 5</td>
<td>4, 5</td>
</tr>
<tr>
<td>Male</td>
<td>22, 9</td>
<td>11, 4</td>
</tr>
<tr>
<td>Male</td>
<td>19, 9</td>
<td>6, 4</td>
</tr>
<tr>
<td>Male</td>
<td>14, 8</td>
<td>4, 3</td>
</tr>
<tr>
<td>Female</td>
<td>17, 1</td>
<td>7, 9</td>
</tr>
<tr>
<td>Female</td>
<td>18, 0</td>
<td>6, 5</td>
</tr>
<tr>
<td>Male</td>
<td>21, 0</td>
<td>7, 7</td>
</tr>
<tr>
<td>Mean</td>
<td>19, 2 (±3, 7)</td>
<td>6, 7 (±2, 2)</td>
</tr>
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</table>

Thus, a purposive sample of participants were recruited from email announcements, flyers, and word of mouth to a variety of local organizations for people with DS. Interested participants contacted the researchers via telephone and were given a description of the task and eligibility requirements for participation. Fifteen participants were screened for eligibility, and 11 participants began the program. Two participants elected to withdraw from the AC intervention, leaving nine participants who completed the study. All protocols were approved by the Human Subjects Institutional Review Board of Arizona State University.

**Intervention**

All participants completed three distinct randomly ordered (refer to Table 2) interventions:

1. **AC**, in which the bicycle's mechanical motor was engaged, which assisted the participants in pedaling at a predetermined rate (i.e., 80 rpm) should they fall below the selected rate for 30 min of active exercise.
2. **VC**, in which the mechanical motor was not engaged and the participants pedaled at their own pace.

### Table 2

**Experimental Design**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
<th>Intervention 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AC</td>
<td>VC</td>
<td>NC</td>
</tr>
<tr>
<td>2</td>
<td>NC</td>
<td>VC</td>
<td>AC</td>
</tr>
<tr>
<td>4</td>
<td>AC</td>
<td>NC</td>
<td>VC</td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td>AC</td>
<td>VC</td>
</tr>
<tr>
<td>7</td>
<td>NC</td>
<td>AC</td>
<td>VC</td>
</tr>
<tr>
<td>8</td>
<td>NC</td>
<td>VC</td>
<td>AC</td>
</tr>
<tr>
<td>9</td>
<td>AC</td>
<td>VC</td>
<td>NC</td>
</tr>
<tr>
<td>10</td>
<td>VC</td>
<td>AC</td>
<td>NC</td>
</tr>
<tr>
<td>11</td>
<td>VC</td>
<td>NC</td>
<td>AC</td>
</tr>
</tbody>
</table>

*Note.* Each participant was randomly assigned Intervention 1, then Interventions 2 and 3, which were separated by approximately one week. AC = assisted cycling, VC = voluntary cycling, NC = no cycling. The same tests (i.e., RT, ToL, PP, EP) were administered in random order before and after each intervention. Note that two participants did not complete the AC condition and their results are not included in the analyses.
own self-selected rate for 30 min of active exercise.

3. NC, in which the participants’ passively listened to a CD of popular music played for 30 min while seated at a desk. Their HRs were about 80 bpm.

During the exercise interventions the participants were seated for 5 min and resting HR was recorded at the end of the rest period. The participants were then seated on the bicycle. Seat height and distance of the bicycle was adjusted for each individual; these measurements were recorded and used for all subsequent testing sessions. Sufficient familiarization/practice time on the bicycle was afforded to the participants, as many adolescents with DS had never ridden a bicycle before. Heart rate was allowed to return to within 5% of resting level in a short break after the practice period. Based on the intervention randomly assigned to the participant for that day, the 30-min intervention was completed as described above. It is important to note that participants were allowed to take breaks as they thought necessary throughout each intervention; however, they were encouraged by the researchers and parents/guardians to continue. All break period start and end times were recorded to ensure that each participant completed the allotted 30 min of active exercise intervention. Three out of the nine participants did take rest breaks. One participant took two, approximately 30-s rest breaks during VC; one participant took a 7-min break during VC and an 8-min break to go to the bathroom during AC, and one participant took a 3-min break during AC.

Heart rate and cadence were the primary measures used to measure exercise intensity and were compared using t tests between exercise sessions. Heart rate and cadence sampling began on the cycling computer at the onset of the exercise and was stopped after 30 min of the intervention, not including rest periods. Researchers manually recorded average and instantaneous HR and cadence from the display of the cycling computer recorded every 5 min during the intervention. Only active HR was included in data analysis; HR sampling continued during elective rest periods but was not included in the average HR recorded. Cadence data were gathered in a similar fashion, such that only active cadence was included in the results. Our results showed that relative exercise intensity as measured by HR was not significantly different between AC and VC interventions. The HR was lower in AC than the VC group (M_AC = 94.1 ± 11.6, M_VC = 97.8 ± 13.8), which is in keeping with the findings of Ridgel et al. (2009) who utilized a similar forced exercise intervention in patients with PD.

As predicted, cadence was significantly greater in AC than VC findings, t(8) = 17.4, p = .000 (M_AC = 81.5 ± 6.93, M_VC = 54.6 ± 11.3). This demonstrates that our AC intervention accomplished the goal of increasing cadence beyond the voluntary rate selected by participants. In the AC intervention, participants cycled at a rate 49.3% greater than the mean self-selected rate in the VC intervention.

Each intervention was separated by at least 1 week to reduce any residual learning effects. Five-minute breaks were given between the pretesting and the onset of exercise as well as between the completion of exercise and the beginning of post-testing.

Tasks and Apparatus

Exercise interventions were completed on a specialized stationary recumbent bicycle that contained an internal motor that would help participants pedal at a predetermined rate when engaged. The bicycle was equipped with platform pedals with a strap and cage device to assist in holding participants feet stable while cycling at a fast rate. Participants were asked to wear athletic shoes and comfortable clothing for all testing days. Participants were seated on the bicycle and asked to hold onto the handles at their sides to ensure their safety. Pedaling cadence was sampled at a rate of 48 Hz by a CycleOps Cervo 2.4 cycle computer (Saris Cycling Group, Madison, WI) wired to a magnetic cadence sensor. Participants wore a Bontrager ANT+ Softstrap Heart Rate belt (Landis Cyclery, Tempe, AZ) that was synchronized with the Cervo 2.4 cycle computer and sampled HR data at a rate of 48 Hz.

The Purdue Pegboard (PP; Lafayette Instrument Company, Lafayette, IN) assessed unimanual and bimanual dexterity. The pegboard had four bins at the top that contained from left to right: pegs, washers, sleeves, and pegs. Directly below the cups were two rows of holes that ran parallel to each other down the center of the board. Adjacent to the first hole was a starting line that participants were asked to place the tips of the fingers on before each trial. The pegboard was placed on the edge of
the table closest to the participants to ensure that the reach was comfortable, and distance to the target was held constant for all participants. Three distinct conditions were assessed, and three trials of each condition were completed: (a) Right hand only; pegs were taken from the right cup one at a time and placed in the right hand column of holes starting at the top. (b) Left hand only; pegs were taken from the left hand cup one at a time and placed in the left hand column of holes starting at the top. (c) Both hands; pegs were taken from the right and left cups at the same time and placed in adjacent holes in a synchronized fashion. Participants were asked to place as many pegs as possible in 30 s for each condition. The Purdue Pegboard was reported as having a test–retest reliability of .92–.96, depending on the condition and no significant practice effects existed (Gallus & Mathiowetz, 2003).

An exercise perception scale specific to people with ID was administered (Heller & Prohaska, 2001). The scale used was a subscale of the Physical Activity and Self Efficacy survey, and it has a .72 test–retest reliability. Because of the acute nature of the exercise, we only measured exercise perception because self-efficacy is a more stable construct that we felt would not change with acute exercise. The Exercise Perception survey had nine questions that asked the participant to rate on a three point Likert scale if “they thought exercise would…”. This is a survey designed to be used with people with ID, and none of the participants had any issues understanding the questions or what was asked of them. Specifically, the exercise perception (EP) survey asked the participants if they thought exercise would help them lose/control their weight, make them feel more/less tired, make their body feel good, make them happier, make them hurt less, help them to meet new people, help them get in shape, make them look better, and improve their health. Questions were repeated as many times as necessary; gestures were also utilized if required to ensure understanding of the survey.

Information processing was measured using a simple reaction time (RT) test following a visual cue. RT was assessed using a Lafayette Instrument Visual RT Apparatus (Model #63035A, Lafayette Instrument Company, Lafayette, IN) and an Economy Clock/Counter (Lafayette Instrument Model #54060, Lafayette Instrument Company). Reliability of RT ranges between .829 and .90 (Hamsher & Benton, 1977). Participants were seated at a desk with the response selection apparatus 20 cm from the edge of the desk. A researcher was seated directly across from the participant with the control panel and clock/counter in front of them. Participants were instructed to push a button with the index finger of their dominant hand as quickly as possible following the stimulus. Participants were given adequate practice (e.g., five trials) to ensure the understanding of instructions. Twenty trials were completed to obtain a reliable measure of RT (Inui et al., 1995). Failure of a trial was defined as when a participant responded with a button-press before the stimulus was presented. These trials were omitted from the results.

The Tower of London (ToL) was the primary outcome measure of cognitive function that specifically assessed cognitive planning ability. The ToL is a subtest from the Developmental Neuropsychological Assessment (NEPSY; Korkman, Kirk, & Kemp, 1998) and its test–retest reliability has been measured at .58–.66 (Lemay, Bédard, Rouleau, & Tremblay, 2004). The ToL consists of a base platform with three pegs of increasing height attached to it. The peg on the participant’s right-hand side could accommodate one ball, the middle peg held two balls, and the last peg held three balls. Three balls were used in this test: red, yellow, and blue. The display board showed the desired ball-peg configuration, and the participants were encouraged to reference it during the test. Participants were shown the desired outcome and given ample time to study it before beginning each trial. They were instructed to complete the puzzle as quickly as possible while remaining within the goal number of moves. The balls were reset to the starting position before each trial. Participants were oriented to the test and explained the rules before testing: (a) Only one ball can be moved at a time; (b) a ball may not be placed on the table or be held in one hand while moving another ball with the other hand; (c) a move cannot be changed once the participant has taken his or her hand off the ball; and (d) self-corrections while the hand is still on the ball are allowed. When a rule violation did occur, researchers moved the ball back to its position before the infraction and testing continued. Before testing began, participants completed two sample trials and were reminded of the rules to ensure understanding. Timing was discontinued when the participants placed the last ball in the correct position.
Researchers counted and recorded the number of moves during each trial. Failure was defined as not completing the puzzle in the allotted time frame, 30 s for the first three puzzles, and 45 s for all remaining puzzles or exceeding the allowed number of moves for each puzzle. Testing was discontinued after participants failed four successive puzzles, or they completed all 17 puzzles (NEPSY).

Procedure
Upon arrival, the participants were introduced to the lab and read (or were read to) and signed assent forms. For all participants, parents/guardians signed a consent form before data collection began. On the first day of testing, each participant’s visual acuity was tested, which was followed by hearing and handedness assessments. Participants then underwent a series of preintervention tests (i.e., RT, Purdue Pegboard, ToL, and EP), which were randomized across each session. Each of the tests was chosen based on the applicability to the participant’s verbal receptive level, which was a better estimation of their abilities than their chronological age. Following a 5-min rest after finishing the exercise intervention, participants completed the same post-intervention assessments as they completed prior to the intervention. The entire testing session lasted on average 2.5–3 hr.

Data Analyses
All normality assumptions were justified using the Shapiro-Wilk test (Shapiro & Wilk, 1965). Thus, separate one-tailed paired t tests were conducted for each dependent measure pre and post each intervention within SPSS version 18 (IBM, Armonk, NY). One-tailed tests were used because predictions were one directional (Thomas & Nelson, 1996). Furthermore, this is appropriate because of the study design, the use of measures that yield quantitative data, and the expectation that participants would improve as a result of the intervention. One-tailed t tests have also been used in exercise intervention studies for other special populations (Toto et al., 2012). Effect sizes were calculated using the pooled standard deviations. Power calculations using G*power (Version 3.1.274; Faul, Erdfelder, Lang, & Buchner, 2007) indicated that we will have sufficient power (1 − β = .80) to detect medium effects with an alpha of .05. The medium effect sizes used to determine the power for this study were based on effect size estimates for pre–post change TOL ($d = 0.56$), PP ($d = 0.62$), and RT ($d = 0.61$) for the AC group in a previous pilot study (Ringenbach, Chen, Albert, Semken, & Semper, 2012).

Results
Purdue Pegboard
In unimanual right and left hand conditions of the Purdue Pegboard, a score was given for the number of pegs placed within the time limit. The score of the bimanual synchronous condition was determined by number of pairs of pegs placed. The total score on the Purdue Pegboard was the sum of the averages of three trials in each condition. As can be seen in Figure 1, manual dexterity, as measured by the mean change in total number of pegs, revealed a significant difference between pre- and post-intervention for the AC session, $t(8) = −1.87, p = .049$, effect size (ES) = 0.23, but not the VC, $t(8) = −0.94, p = .199$, or NC, $t(8) = −0.39, p = .35$, sessions.

Exercise Perception
The exercise perception scale score was the primary outcome measures of the participants’ perception of exercise. Exercise perception significantly improved between pre- and post-intervention in the AC session, $t(8) = −2.09, p = .036$, ES = .38, but not in the VC, $t(8)= −0.53, p = .31$, or NC, $t(8) = −1.75, p = .08$, sessions.

Figure 1. Mean difference pre-post in movement time for the Purdue Pegboard as a function of exercise session. *p < .05.
RT
RT was determined as the arithmetic mean of the 20 trials. As can be seen in Figure 2, speed of information processing, as measured by simple RT, was significantly decreased from pre- to post-intervention for the AC session, $t(8) = 2.29, p = .026, ES = .45$, but not for the VC, $t(8) = -0.12, p = .45$, or NC, $t(8) = -0.49, p = .32$, sessions.

ToL
The ToL was scored by the number of correctly completed puzzles. A puzzle was deemed incorrect if it was not completed within the time limit, or if participants required more moves to complete the puzzle than the move limit allowed. As can be seen in Figure 3, cognitive planning ability as measured by scores on the ToL, approached conventional levels of significant difference between pre- and post-intervention for the AC session, $t(8) = -1.69, p = .065, ES = .74$, but not the VC, $t(8) = 0.15, p = .44$, or NC, $t(8) = 0.27, p = .40$, sessions.

It is important to note that ES describes the strength of the relationship, not significance level, so they cannot always be compared across tasks. Furthermore, the descriptions of moderate and high are somewhat arbitrary and are relative to the task. As can be seen in our results, some results with high ES were not as significant as others with low ES. We believe this is related to different levels of variability associated with each task and its associated measures.

Discussion
This is the first study, to our knowledge, that has utilized an AC intervention in adolescents with Down syndrome and measured changes in upper extremity movement and cognitive functioning. Enhancing movement and cognitive functioning is critical to improving ADLs and fostering independence and improving quality of life for people with DS.

Movement Functioning
Our results support the prediction that significant improvements in manual dexterity as assessed by the Purdue Pegboard were seen pre and post the AC intervention, whereas no differences in manual dexterity were seen pre and post the VC and NC interventions. Our results are consistent with animal and recent human research. In the PD rodent model, it was found that forced exercise resulted in upregulated neurotrophic factors and neuroprotective effects thought to improve functional movement skills (e.g., locomotion, reaching; Tajiri et al., 2009). In people with PD, Ridgel and colleagues (2019) compared Forced/AE and VE groups in patients with PD. They measured bimanual dexterity with a bimanual complimentary force control task similar to opening a bottle (Alberts, Elder, Okun, & Vitek, 2004; Alberts, Okun, & Vitek, 2008). They found improved coupling of grasping forces, interlimb coordination, and rate of force production after AE (Ridgel et al., 2009) but not VE. What is similar about these populations is that both PD and DS have
compromised CNS functioning, which leads to deficits in movement speed, force control, and coordination. AC is suggested to improve whole body movement function. The fact that a lower leg exercise improved upper extremity movement function indicates that improvements are happening at the cortical level. Upregulation of brain-derived neurotrophic factor (BDNF) is one proposed mechanism accounting for whole body movement function improvement following assisted lower limb exercise (Ridgel et al., 2009). Future research will continue to examine the mechanisms responsible for improvements in whole body movement functioning following AC interventions.

Participant’s Perceptions Toward Exercise
Our results were somewhat consistent with the prediction that participants’ perceptions towards exercise would improve after an exercise intervention. Interestingly, exercise perception only improved following the AC session and not both the AC and VC sessions as predicted. One interpretation is that during the AC intervention but not VC intervention, the participants felt less tired and sore, hence happier because they were pedaling with the assistance of a mechanical motor, which made it more fun and less work (e.g., lower HR). Furthermore, because they were pedaling at such a fast rate, they perceived that they were more likely to get into shape, look better, improve their health, and lose weight. Improvements in exercise perception may be of particular benefit to populations with DS, who typically have low motivation to exercise (Barr & Shields, 2011). The sedentary lifestyle of this population may in part be explained by low motivation and poor attitudes toward exercise (Jobling & Cuskelly, 2002; Pastore et al., 2000). Future research will continue to examine the relationship between chronic exercise interventions and perceptions of exercise. It is thought that long-term exercise interventions may have more profound effects on exercise perception and exercise self-efficacy measures.

Information Processing
Our results supported the prediction that information processing as assessed by simple RT improved following AC, but did not show any improvements after VC or NC. Recent literature has localized brain activation during RT tasks to the frontomedial cortex, left inferior prefrontal cortex, inferior frontal gyrus, and middle frontal gyrus (Koechlin, Ody, & Kouneiher, 2003; Liu, Liao, Fang, Chu, & Tan, 2004; Werheid, Zyss, Müller, Reuter, & von Cramon, 2003). The prefrontal cortex continues to be indicated as a primary area responsible for various cognitive function tasks, including RT (Dalley, Cardinal, & Robbins, 2004; Koechlin & Summerfield, 2007). The results of the present study may be explained by a proposed mechanism of up-regulation of neurotrophic proteins in the prefrontal cortex following assisted exercise (Alberts et al., 2011). Thus, functional magnetic resonance imaging (fMRI) research is needed to determine the role of specific prefrontal gyri with respect to their role in various cognitive functioning tasks in people with DS.

Cognitive Planning
Our results somewhat supported the prediction that cognitive planning as assessed by the ToL approached conventional levels of significance for improvement following AC, but did not show improvements after VC or NC. The ToL paradigm has been found to activate the dorsolateral prefrontal cortex, anterior cingulate cortex, caudate nucleus, (pre)cuneus, supramarginal and angular gyrus of the parietal lobe, and frontal opercular areas of the insula (Dagher, Owen, Boecker, & Brooks, 1999; Lazeron et al., 2000; Newman, Carpenter, Varma, & Just, 2003). This finding is in keeping with proposed effect of forced exercise on cognitive function as demonstrated by activation of the prefrontal cortex found by Alberts and colleagues (Alberts et al., 2011). It has been proposed that increased afferent information produced by the high pedaling rate of assisted exercise paradigms produces molecular level changes at the cortical level, including up-regulation of the neurotrophic factors (e.g., BDNF, glial cell-derived neurotrophic factor, insulin-like growth factor; Alberts et al., 2011). Further studies should continue to examine the cortical level mechanisms associated with increases in cognitive function following AE.

Limitations and Summary
The present study should be considered a pilot study because of the small sample size, which reduces its power, although the information is valuable because we do not know enough about how to motivate and get adolescents with DS
active. Generalizations should be cautious considering there were only three female participants and high variability in chronological and verbal receptive level, which is typical of children, especially special populations (Buckley, 1993). Furthermore, repeated pre- and post-testing of similar measures leads to the potential of practice effects. Specifically, the ToL test has been suggested to be somewhat influenced by practice effects (Lemay et al., 2004). Ordering of the interventions could also be a potential confound although we attempted to ameliorate this by randomizing the order of the interventions across all participants (refer to Table 2).

Our results, however, are important in that an acute bout of assisted cycling was shown to have positive effects on information processing, cognitive planning, exercise perception, and manual dexterity in adolescents with DS. This information is important to researchers, clinicians, and professionals in policy making because current exercise recommendations for people with DS vary greatly and results on improvement of motor and cognitive functioning are limited. Furthermore, the type and intensity of exercise for adolescents with Down syndrome has not been mandated. Our research shows that exercise must occur at a fast rate (e.g., 35% greater than preferred rate) for improvements in motor and cognitive function in adolescents with DS.

### References


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