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# Improving Upper Extremity Motor Control in Adults With Autism Spectrum Disorder and an Intellectual Disability Through Participation in an Adapted Physical Exercise Intervention

## *Améliorer le contrôle moteur des membres supérieurs chez les adultes ayant un trouble du spectre de l'autisme et une déficience intellectuelle par la participation à une intervention d'exercice physique adapté*

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### Keywords

autism spectrum disorder,
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### Abstract

*This study sought to quantify the impact of a 12-week adapted physical exercise (APEX) program on upper extremity motor control in 11 adults diagnosed with both autism spectrum disorder and an intellectual disability (ASD-ID). Motor planning and execution during an upper-limb reaching movement was assessed at baseline, mid-, and post-program. Overall, participants became more efficient at preparing and executing the task, needing fewer adjustments during the movement to achieve similar accuracy. Eight participants also improved their response programming. The multi-modal APEX program appears to be an effective intervention for improving upper extremity motor control in adults with ASD-ID. Improving motor skills may lead to increased participation in physical activity, greater independence, and improved quality of life for adults with ASD-ID.*

### Résumé

Cette étude visait à évaluer l'effet d'un programme d'exercice adapté (APEX) de 12 semaines sur le contrôle moteur des membres supérieurs auprès de 11 adultes ayant un trouble du spectre de l'autisme et une déficience intellectuelle (TSA-DI). La planification et l’exécution motrices lors d’un mouvement d’étirement des membres supérieurs ont été évaluées au niveau de base, à la moitié du programme et à la suite de celui-ci. Globalement, les participants sont devenus plus efficients dans la préparation et l’exécution du mouvement, et ont nécessité de moins en moins d’ajustements pour atteindre un niveau semblable de précision durant le mouvement. Huit participants ont également amélioré leur programmation de la réponse motrice. Le programme multimodal APEX semble être une intervention efficace pour améliorer le contrôle des membres supérieurs chez les adultes ayant un TSA-DI. Le développement des habiletés motrices pourrait mener à une participation accrue à l’activité physique, à une plus grande indépendance et à une meilleure qualité de vie pour ceux-ci.

**Mots clés :** trouble du spectre de l’autisme, déficience intellectuelle, adultes, exercice physique adapté, contrôle moteur.

## Introduction

Recent research has documented deficits in motor skill abilities in persons with autism spectrum disorder (ASD: Bhat, Landa, & Galloway, 2011; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010) and in persons with intellectual disabilities (ID: Carmeli, Bar-Yossef, Ariav, Levy, & Lieberman, 2008; Enkelaar, Smulders, van Schrojenstein Lantman-de Valk, Geurts, & Weerdesteyn, 2012), in comparison to typically-developing peers. These deficits include difficulties with gait, balance, upper extremity coordination, and motor planning and execution. With respect to motor planning and execution, individuals with ASD and/or ID take longer to plan and execute movements (Nazarali, Glazebrook, & Elliott, 2009; van Biesen et al., 2010), and individuals with ASD have more difficulty in reprogramming planned movements (Nazarali et al., 2009), than their typically-developing peers. These motor planning and execution deficits are apparent in early childhood, and although they do improve with age, they tend to remain below the levels of typically-developing peers into adulthood (Bhat et al., 2011; Selickaitė, Rėklaitienė, & Požėrienė, 2014; Sokhadze, Tasman, Sokhadze, El-Baz, & Casanova, 2016). Given the 31% co-occurrence rate of ASD and ID (ASD-ID: Centers for Disease Control and Prevention [CDC], 2014), it is likely that individuals with ASD-ID would also present with motor impairments; however, it is not possible to separate the individual effects of each diagnosis on motor abilities. Nevertheless, considering movement skills are essential for performing activities of daily living, recreation, and employment (Carmeli et al., 2008), interventions aimed at improving these skills are needed.

In addition to the general health and fitness benefits, participation in exercise and sports/recreational activities may be one avenue for promoting motor skill development in adults with ASD-ID (Sowa & Muelenbroek, 2012). Specifically, typically-developing participants demonstrated that regular participation in physical activities such as aerobic conditioning, exergaming, racket sports, and strength training improved participants’ upper limb motor planning and task execution (e.g., Dustman et al., 1984; Ellemberg & St. Louis-Deschênes, 2010; Maillot, Perrot, & Hartley, 2012; Spirduso, 1975). However, the research in this area involving adults with ASD-ID is limited. The participants in most studies investigating the general health and fitness benefits of participation in exercise and sports/recreational activities for individuals with ASD-ID were either children or adolescents. Systematic investigations of the benefits of exercise for motor skill development in adults with ASD and/or ID are scarce (Azar, McKeen, Carr, Sutherland, & Horton, 2016). Thus, the objective of this study was to quantify the impact of a 12-week adapted physical exercise (APEX) program on upper extremity motor planning and execution in adults diagnosed with ASD-ID. The APEX program provided a combination of cardiovascular and strength training, along with a sports and recreational activities component. It was hypothesized that improvements in motor planning and execution would occur at each subsequent test period.

## Materials and Methods

### Participants

Fourteen adults diagnosed with ASD-ID participated in a 12-week APEX program (age range = 18-62 years; two females; IQ scores from previous clinical assessment = 20-70). To be included in the study, participants were required to: 1) be 18 years of age or older; 2) have diagnoses of both ASD and an ID; 3) provide a Physical Activity Readiness Medical Examination form signed by their physician; 4) be capable of following instructions and completing a physical activity regimen with guidance from an instructor; and 5) commit to attending all exercise and testing sessions. Participants were excluded from the study if they had a history of violent or aggressive behavior.

The participants’ legal guardians provided their informed consent prior to the start of the program. Participants also provided assent (written or verbal, depending on cognitive ability) following a simplified explanation and a demonstration of the tasks they would be required to complete. The University of Windsor’s Research Ethics Board approved all study procedures.

All procedures were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

### APEX Program

Each participant was paired with an instructor (1:1 ratio) to complete two 90-minute exercise sessions per week over a 12-week period. The instructors were undergraduate and master’s level students from the Kinesiology and the Interdisciplinary Arts & Science programs at the University of Windsor. Consistent with the Canadian Society for Exercise Physiology guidelines (2011), each session included a five-minute warm-up (preparatory activities and functionally-based movements), 20 minutes of cardiovascular exercise (cycling on a stationary bike at a moderate intensity), 20 minutes of whole-body strength training (machines and free weights, 2 sets of 8-10 repetitions, 60 seconds of rest between each set), 30 minutes of sports and recreational activities (e.g., playing catch with a foam football, shooting basketballs, badminton rallies, etc.), and a five-minute cool-down (whole-body static stretching**)**. Specific upper body strength exercises included a chest press, shoulder press, bicep curl, and triceps extension. For a complete description of the APEX program see Carr, Horton, Sutherland, and Azar (2014). During the sports and recreational activities component, instructors initiated games of catch, shooting basketballs, or games of “back and forth” with the badminton rackets, which challenged participants' upper extremity visual-motor coordination. The fitness instructors also provided feedback throughout the APEX program in the form of one-on-one verbal communication, modelling, gentle physical assistance, and pictures.

Fitness (resting heart rate and blood pressure, flexibility, upper- and lower-body isometric strength, cardiovascular fitness) and motor skills (gait, static balance control, upper extremity motor planning and execution) were assessed at baseline, mid-, and post-program. Prior to the baseline test session, participants attended a familiarization session where they underwent the full testing protocol to ensure they could complete the tests reliably. Three participants were unable to consistently provide valid trials with both hands in each test period, thus they were excluded from the analysis. This report will focus on the results of the upper extremity motor planning/execution test from a subset of 11 participants (age range = 21-49 years [*M*: 34.5, *SD*: 9.4], two females, IQ scores from previous clinical assessment = 20-70). All participants attended and completed all sessions during the program (i.e., no attrition).

## Test Apparatus and Procedure

The test apparatus included a Toshiba Portege M750-10J touch screen laptop (21.5 cm wide x 28.5 cm long) and its accompanying stylus, which was equipped with an infrared-emitting diode (IRED) reference plane. Positional data (i.e., x, y, z coordinates: see Figure 1) of the IREDs were obtained using a NDI 3D Investigator Motion Capture System (Northern Digital Inc., Waterloo, ON, Canada), which allowed for the computation of the location of the tip of the stylus in three-dimensional space. Customized LabView software (National Instruments, Austin, TX, USA) presented visual targets on the laptop screen at varying time intervals and triggered the motion capture system to start recording. Participants performed aiming movements with the stylus in response to the appearance of the targets on the touch screen. The motion capture system recorded the position of the reference plane at a sampling rate of 500 Hz.

The touchscreen was aligned horizontally with the surface of the table and located 6 cm from the edge of the table. Participants were seated at the table with their midlines centered with the touch screen (see Figure 1). A start position (4 cm x 4 cm, black cross) and a single target (6 cm diameter, solid black circle) were displayed on the touch screen. The start position was located 4 cm from the proximal edge of the touch screen and the target was located 10 cm center-to-center from the start position. To begin a trial, participants aligned the stylus with the center of the start position. As soon as the stylus was aligned, a tone would sound warning the participants that the trial was about to begin. The target was then presented following a variable fore-period of 1,500 – 2,500 ms. As soon as the target appeared, participants were required to move the stylus as quickly and accurately as possible by lifting it from the start position and touching down on the target. Each movement was made as an extension from the midline of the participant outward. Participants were asked to perform 15 trials per hand at each test session. The order of hand used was counterbalanced between participants during each test session.

We chose a simple task to assess motor planning and execution so that the participants would be able to learn it quickly. This task was chosen rather than the ruler drop reaction time (RT) test, which we knew from previous experience that participants would find challenging because of the apparatus used (Azar et al., 2016). Similar tasks (i.e., upper limb reaching movements) have been used to investigate motor planning and execution in individuals with Down syndrome (e.g., Lawrence et al., 2013) and in individuals who developed typically (e.g., Bested, Khan,

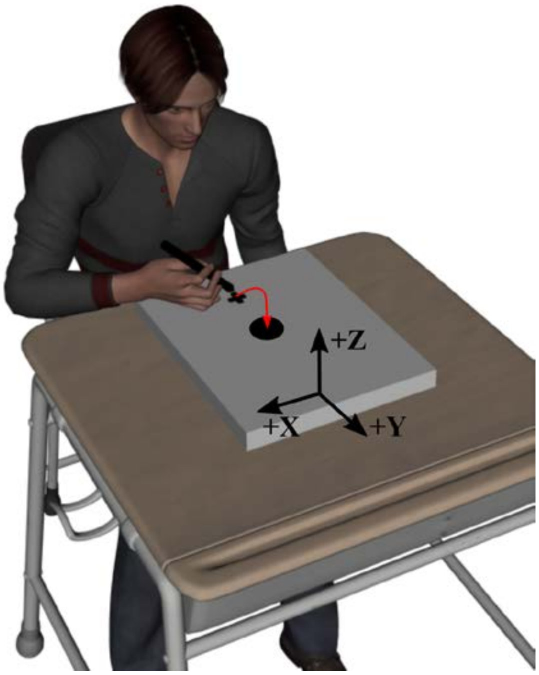

Figure 1. *Three-dimensional representation of the experimental set-up, where aiming movements were made away from the body (i.e., y-axis) using a stylus on a touch-screen computer.*

Lawrence, & Tremblay, 2018; Khan, Mottram, Adam, & Buckholz, 2010; Khan, Sarteep, Mottram, Lawrence, & Adam, 2011).

### Data Reduction

The position data were low-pass filtered using a second order, dual-pass Butterworth filter with a cut-off frequency of 16 Hz (Khan et al., 2011). The filtered position data were differentiated to obtain velocity data, from which the peak resultant velocity was located. The onset of movement was determined by moving backward from peak velocity until the instant where vertical velocity fell below 15 mm/s, and the end of the movement was defined as the instant after peak velocity where the vertical velocity fell below 15 mm/s (Khan et al., 2011).

### Dependent Variables and Statistical Analyses

Operational definitions of the dependent variables are listed in Table 1. To account for potential short-term learning effects, the first five of the 15 trials for each hand were considered practice and were removed from each participant’s data set (Khan et al., 2011), yielding 10 trials per hand. From previous experience (Azar et al., 2016), we anticipated that the participants' performance would be highly variable (i.e., in the magnitudes of the dependent variables, as well as in the number of valid trials each participant would be able to produce), both between participants and within participants at different test sessions. Indeed, the number of useable trials produced by each participant varied – some trials were removed from the analysis because the participants did not move, or because markers were occluded. Furthermore, the mean and standard deviation of each participant's trials were calculated, and any trials that were more than two standard deviations away from the mean were also removed (Stevens, 1996). The lowest number of useable trials produced by any one participant was five; therefore, only the first five useable trials for every participant were entered into the statistical analysis, so that the number of trials each participant contributed to the analysis would be standardized.

Table 1. *Dependent Variables (Abbreviations and Operational Definitions) in Order From the Movement Planning Phase (i.e., RT) to Movement End (i.e., EaEnd)*

| Dependent Variables | Operational Definition |
|---|---|
| Reaction time (RT) | Time from presentation of target on the touch screen to stylus lift-off from the start position (ms). |
| Movement time (MT) | Time from stylus lift-off to touch down on target (ms). |
| Time to peak velocity (TtPV) | Duration of time taken to reach peak velocity from stylus lift-off (ms). |
| Peak velocity (PV) | Maximum velocity reached during the movement from lift-off until movement end (mm/s). |
| Ellipse area (EA) at peak velocity (EaPV) | A measure of spatial variability of peak velocity in the x-y movement axes as per Hansen, Elliott, & Khan, (2008). Calculated using within-subject standard deviations of x- and y-positions ($EaPV = \pi \times SDx \times SDy$, units: $mm^2$). |
| Time after peak velocity (TaPV) | Duration of time taken after peak velocity until stylus touch down (ms). |
| TtPV/TaPV | Ratio of TtPV/TaPV. (Values > 1 indicate more time taken to peak velocity than after peak velocity). |

| | |
|---|---|
| Constant error, primary axis (CEy) | Error along the primary movement axis calculated in relation to the center of the target. Constant error has a positive value if the center of the target was overshot and negative if undershot (mm). |
| Constant error, secondary axis (CEx) | Error along the secondary movement axis calculated in relation to the center of the target. CEx has a positive value if right of target center and negative if left of target center (mm). |
| Variable error, primary axis (VEy) | Variable error along the primary movement axis (within-subject standard deviations of CEy: mm). |
| Variable error, secondary axis (VEx) | Variable error along the secondary movement axis (within-subject standard deviations of CEx: mm). |
| EA at movement end (EaEnd) | A measure of spatial variability of movement end in the x-y movement axes as per Hansen et al. (2008). Calculated using within-subject standard deviations of x-and y-positions ($EaPV = \pi \times SDx \times SDy$, units: $mm^2$). |

The participants' average scores ($n = 5$) at each test session were entered into a series of Linear Mixed Models to determine whether the dependent variables (respectively) differed across the three test sessions for each hand. Fixed effects included Session (baseline, mid-program, post-program), Hand (left, right), and a Session × Hand interaction term. The models for Ellipse Areas (EA) at peak velocity (EaPV) and movement end (EaEnd) also included fixed effects of Kinematic Index (peak velocity, movement end), and all possible interaction terms. Session, Hand, Kinematic Index, and the interaction terms were also modelled as random effects (random slopes and intercepts) using four different random covariance structures (compound symmetry [CS], heterogeneous compound symmetry [CSH], first-order auto-regressive [AR1], and heterogeneous first-order autoregressive [ARH1]). Session, Hand, and Kinematic Index were identified as repeated observations, and were modelled with four different repeated covariance structures (CS, CSH, AR1, and ARH1). Thus, 36 different models were tested for each dependent variable (fixed effects only, random effects only, fixed and random effects combined, with all possible combinations of random and repeated covariance structures). The models with the lowest Schwarz's Bayesian Criterion (BIC) were chosen for analysis (Seltman, 2015). Effect sizes were calculated for all main effects and interactions (omega squared: $\omega^2$). Significant main effects and interactions ($\alpha < 0.05$) were evaluated further using pairwise comparisons of the model-predicted estimated marginal means. All statistical analyses were conducted using SPSS version 23 (IBM Corporation, Armonk, NY, USA).

## Results

For every dependent variable, models including only fixed effects yielded the best fit. Thus, the results presented below are based on models including fixed effects only. Most of the best-fitting models included the CS repeated covariance structure, except for the models for RT (CSH), TaPV (CSH), $VE_x$ (ARH1), $VE_y$ (CSH), and EaPV/EaEnd (ARH1).

Table 2. Means (SD) of Dependent Variables Across Test Sessions

| Dependent Variables | Test Session | | | | | |
|---|---|---|---|---|---|---|
| | Baseline | | Mid-program | | Post-program | |
| RT (ms) | 521 | (438) | 464 | (291) | 372 | (134) |
| MT (ms) | 501 | (194) | 440[a] | (120) | 417[a] | (145) |
| PV (mm/s) | 480 | (142) | 500 | (143) | 514 | (181) |
| TtPV (ms) | 140 | (26) | 136 | (38) | 149 | (52) |
| TaPV (ms) | 361 | (196) | 304 | (114) | 268[a] | (118) |
| TtPV/TaPV | 0.50 | (0.26) | 0.50 | (0.19) | 0.63[a] | (0.26) |
| EaPV (mm²) | 133 | (182) | 88 | (56) | 116 | (112) |
| EaEnd (mm²) | 61 | (63) | 50 | (51) | 52 | (37) |
| CEy (mm) | -2.3 | (4.2) | -3.4 | (4.5) | -3.0 | (7.6) |
| CEx (mm) | 0.00 | (3.1) | -0.26 | (4.6) | 0.49 | (4.2) |
| VEy (mm) | 4.0 | (2.0) | 4.2 | (1.8) | 6.2 | (8.9) |
| VEx (mm) | 4.5 | (3.3) | 3.3 | (1.9) | 3.5 | (1.2) |

[a] = significantly different from baseline ($p < .05$)

### Movement Time (MT)

There was a significant main effect of Session on MT [$F(2, 49.0) = 5.74$, $p = .006$, $\omega^2 = 0.22$]. Participants significantly decreased their MT from baseline (*M*: 501 ms, *SD*: 194 ms) to mid-program (*M*: 440 ms, *SD*: 120 ms, $p = .02$) and post-program (*M*: 417 ms, *SD*: 145 ms, $p = .002$: see Figure 2).

### Time After Peak Velocity (TaPV*)*

There was a significant main effect of Session on TaPV [$F(2, 23.0) = 5.45$, $p = .01$, $\omega^2 = 0.21$]. Participants took significantly less TaPV at post-program (*M*: 268 ms, *SD*: 118 ms) compared to baseline (*M*: 361 ms, *SD*: 196 ms, $p = .009$: see Figure 2).

### Ratio of Time to Peak Velocity/ Time After Peak Velocity (TtPV/ TaPV)

There was a significant main effect of Session on TtPV/TaPV [*F*(2, 49.1) = 4.40, *p* = .02, $\omega^2$ = 0.17]. Participants significantly increased their TtPV/TaPV ratios from baseline (*M*: 0.50, *SD*: 0.26) to post-program (*M*: 0.63, *SD*: 0.26, *p* = .01). This difference was largely driven by the changes in TaPV, since there were no significant changes in TtPV across test sessions [*F*(2, 49.2) = 0.90, *p* = .41, $\omega^2$ = 0.00].

### Ellipse Areas (EA)

There was also a main effect of Kinematic Index for EA [*F*(1, 31.1) = 16.64, *p* = .0003, $\omega^2$ = 0.42], such that EaPV (*M*: 112 mm², *SD*: 127 mm²) was significantly larger than EaEnd (*M*: 54 mm², *SD*: 51 mm²). All other main effects and interactions were non-significant (see Table 2).

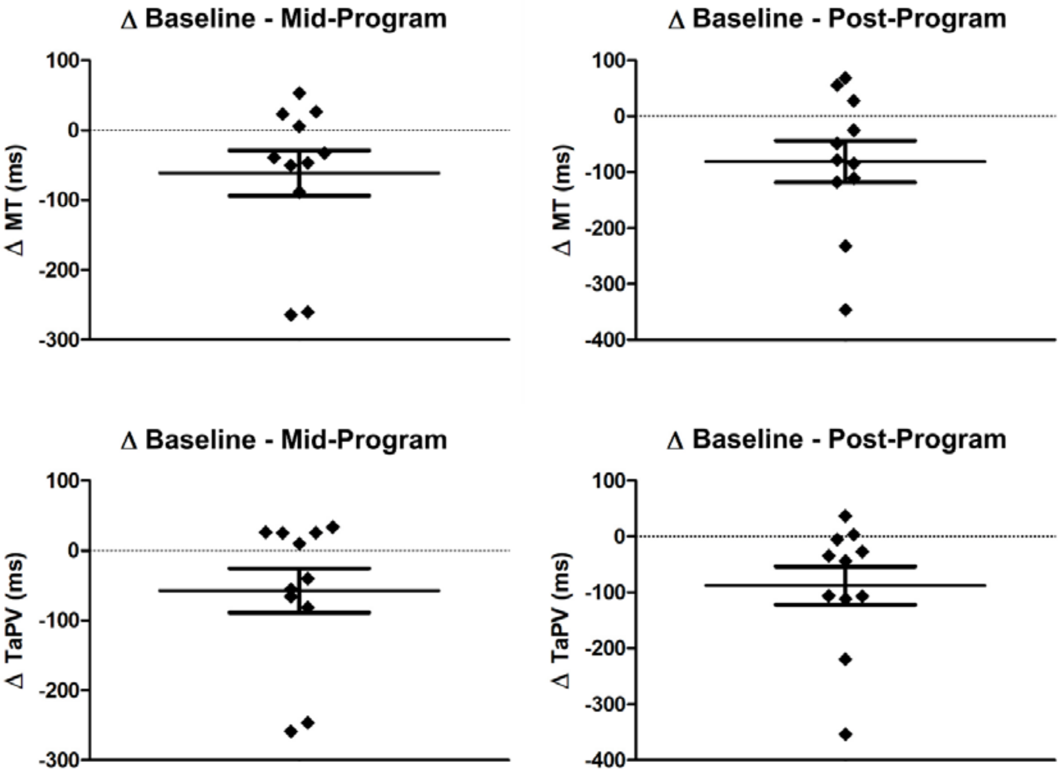

Figure 2. *Vertical scatterplots depicting individual differences from Baseline to Mid- and Post-Program for both movement time (MT) and time after peak velocity (TaPV). Top-panel: Difference in MT from Baseline to Mid- and Post-Program. Bottom-panel: Difference in TaPV from Baseline to Mid- and Post-Program. Note: Bars represent the mean and SEM, while individual participants' differences are represented by each symbol. A symbol that appears below the dotted line identifies a participant who showed an improvement between sessions.*

## Discussion

The purpose of this study was to determine whether participation in a 12-week APEX program would improve upper extremity motor planning and execution in adults with ASD-ID. Overall, participants improved their ability to use visual cues/feedback to adjust their movements and complete the task accurately. Participants significantly reduced the amount of time taken to perform the task as a result of improved response programming and task execution, with no significant changes in movement errors. Participants also showed a substantial improvement in RT across test sessions, yet the differences between these sessions were not statistically significant, likely due to a high between-participant variability in RT performance. A follow-up analysis of percent change across each testing period revealed that eight out of 11 participants showed improvement in RT from baseline to mid-program in one or both hands (*M*: 17 %, *SD*: 13 %), and seven out of 11 participants showed improvement in RT from baseline to post-program in one or both hands (*M*: 35 %, *SD*: 28 %). Thus, despite the variability in performance, most participants exhibited an improvement in motor planning (i.e., RT).

Reaction time is considered an indicator of response programming and is known to increase with task complexity (Henry & Rogers, 1960; Klapp, 1995). Since task complexity remained constant in this study, the reduction in RT exhibited by most participants suggests that these individuals became more efficient in their response programming over the course of the APEX program. Furthermore, participants showed substantial (but not statistically significant) improvements in EaPV from baseline (*M*: 133 $mm^2$, *SD*: 182 $mm^2$) to both mid-program (*M*: 88 $mm^2$, *SD*: 56 $mm^2$) and post-program (*M*: 116 $mm^2$, *SD:* 112 $mm^2$). This also suggests improvements in motor planning, as EaPV has been used to evaluate whether errors have occurred during the programming of the movement (Elliott, Helsen, & Chua, 2001). Time after peak velocity (i.e., TaPV) is the error-correction phase of the movement – a higher TaPV indicates that more discontinuities or corrections are being made to reduce error at the target (Elliott, Carson, Goodman, & Chua, 1991; Elliott et al., 2010; Elliott et al., 2001). A reduction in spatial variability (i.e., EA) from peak velocity to movement end would also suggest that visually-based online control processes were used (Khan et al., 2011; Khan, Lawrence, Buckholz, & Franks, 2006). In the present study, EaPV (*M*: 112 $mm^2$, *SD*: 127 $mm^2$) was significantly larger than EaEnd (*M*: 54 $mm^2$, *SD*: 51 $mm^2$), indicating that participants used online control processes during the latter half of the movement. Furthermore, TaPV decreased over the course of the program, yet there were no significant changes in any of the error variables. This suggests participants needed fewer corrections to achieve a comparable level of accuracy. Fewer corrections led to shorter movement times and thus, more efficient movements. Taken together, these findings suggest that over the course of the program, participants became more efficient at preparing (i.e., decrease in RT and EaPV) and executing (i.e., decrease in MT) the task, and needed fewer online adjustments during the movement (i.e., decrease in TaPV) to achieve the same level of accuracy (i.e., no change in error measures).

The simplicity of the task might explain why there were no significant changes in any of the error scores over the course of the program. The simple forward reaching motion was considered an easy task due to the large target size (6 cm) and smaller movement amplitude (10 cm) in comparison to other studies; for example, Khan et al. (2010) used 2.5 cm target widths and movement amplitudes of 15 cm. The participants' errors were already very low at baseline ($CE_x$, *M*: 0.0 mm, *SD*: 3.1 mm; $CE_y$, *M*: -2.3 mm, *SD*: 4.2 mm), and although they did show increases in error scores in the primary movement axis (i.e., approximately 30% in $CE_y$ and 50% in $VE_y$), these were not statistically significant ($p > .05$, $\omega_p^2 \leq 0.02$) or functionally relevant (i.e., less than 2.5 mm within a 60 mm target). Another explanation is that the participants' MTs for this task were much longer than those of adults who developed typically, even after the conclusion of the program [e.g., *M*: 417 ms, compared to *M*: 128 ms reported by Khan et al. (2010)]. When normalized to movement distance, the participants' MTs (e.g., 417 ms/10cm ≅ 42 ms/cm) were within the range previously reported for adults with ASD (27-64 ms/cm: Glazebrook, Gonzalez, Hansen, & Elliott, 2009; Nazarali et al., 2009), and were longer than those reported for adults with Down syndrome (27 ms/cm: Lawrence et al., 2013). This would have given them ample time to perform corrections and produce accurate movements.

Although it appears the APEX program was effective in improving participants' motor control, the current investigation did not include a standardized control group. Therefore, we suggest that a future study include a control group as we cannot entirely rule out the possibility of learning effects**.** Nevertheless, the magnitudes of the differences across trials suggest that the program did have some impact. Furthermore, the participants were not exposed to the computerized test between testing sessions (spaced by a minimum of four weeks), and they were not given any additional practice on the test days beyond the 15 trials per hand. The comparison of each participant to their own baseline measurements, as well as the removal of the first five trials in each testing session, would have helped to control for short-term learning effects within each session and are common practice in the motor control literature (e.g., Adam, Helsen, Elliott, & Buekers, 2001; Lavrysen et al., 2003).

The APEX program provided a combination of cardiovascular and strength training, along with a sports and recreational activities component. Many activities within the latter (e.g. catch, badminton) would have directly challenged participants' visuomotor coordination, requiring them to respond quickly and adjust their movements online (i.e., during movement execution). However, prior research has demonstrated that regular participation in physical activity – including aerobic conditioning, strength training, and/or racket sports (including "exergaming") – has a positive influence on motor planning and execution (e.g., Clarkson, 1978; Dustman et al., 1984; Ellemberg & St. Louis-Deschênes, 2010; Maillot et al., 2012; Spirduso, 1975). Thus, we cannot draw definitive conclusions as to which specific components of the intervention led to the observed improvements, and it is possible that all components of the study played a role in the improvement in visuomotor coordination.

Individuals with ASD and/or ID have been shown to take longer to plan and execute movements than their typically-developing peers, (Nazarali et al., 2009; van Biesen, et al., 2010). Our findings suggest that the APEX program was an effective intervention for improving upper extremity motor planning and execution in adults with ASD-ID. Given the importance of motor skills in performing activities of daily living, recreation, and employment (Carmeli et al., 2008), improving motor skills may lead to increased participation in physical activity, greater independence, and improved quality of life.

## Key Messages From This Article

**People with disabilities.** Participating in an exercise program can enhance your physical, social, and mental health. However, getting involved in regular exercise can also improve your ability to use your upper arms. Better upper arm control can make it easier for you to perform activities of daily living, participate in recreational activities, and complete employment tasks.

**Professionals.** It is important for adults with ASD-ID to engage in sports and games activities as these may enhance their motor skills, which could translate to improved ability to perform daily tasks. This increase in motor control could help adults with ASD-ID engage in more volunteer and employment opportunities, which will promote greater independence and quality of life.

**Policymakers.** Policy to develop exercise programs for adults with ASD-ID would assist in promoting motor skill development, which may lead to greater independence and quality of life.

## Messages clés de l'article

**Personnes ayant une incapacité :** Participer à un programme d'exercice peut favoriser votre santé physique, sociale et mentale. Pratiquer une activité physique sur une base régulière peut également vous aider à utiliser vos bras. Un meilleur contrôle de ceux-ci pourrait vous aider dans vos activités quotidiennes, récréatives et professionnelles.

**Professionnels :** Il est important pour les adultes ayant un TSA-DI de participer à des activités sportives et de jeux. Ces activités pourraient favoriser l'amélioration de leurs habiletés motrices pour effectuer leurs tâches quotidiennes. Cette amélioration du contrôle moteur pourrait ainsi promouvoir leur implication dans des activités bénévoles ou professionnelles, ce qui favoriserait leur indépendance et leur qualité de vie.

**Décideurs :** Les politiques concernant le développement de programmes d'exercice pour les adultes ayant un TSA-DI pourraient contribuer à la promotion du développement de leurs habiletés motrices, lesquelles favoriseraient une indépendance accrue et une meilleure qualité de vie.

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