Sensorimotor Impairments and Strategies in Adults With Intellectual Disabilities

Eli Carmeli, Tamar Bar-Yossef, Claudette Ariav, Rosy Paz, Hanna Sabbag, and Ran Levy

Adults with intellectual disabilities (ID) show a greater tendency toward deconditioning and having a sedentary lifestyle than their peers without disabilities. The aim of this study was to characterize sensorimotor deficits through coordination tests and during static and dynamic balance. Eight tasks that involved the integration of hand movements with visual information were used here, as well as the Posture Scale Analyzer system to examine postural stability. During static and dynamic standing tests with the eyes closed, the postural stability of people with ID was accompanied by a small sway rate. In the ID group, the frontal plane movements were significantly larger ($p > .05$) than the sagittal plane movements. The participants with ID showed a significantly lower score than the control group in all the sensorimotor tests. Our observations on balance and coordination capabilities might have significance for understanding the mechanisms underlying movement dysfunction in adults with ID and offer some new approaches for their possible prevention.

Keywords: sensorimotor impairments, balance, coordination, intellectual disabilities

The neuromuscular system allows movement to be performed in a variety of ways, and it is able to adapt to different environmental conditions. Understanding movement impairments in people with intellectual disabilities (ID) and the relationships between these impairments and balance and coordination is fundamental to the development of successful rehabilitation therapies. Moreover, adults with ID show signs of premature aging with a greater tendency toward deconditioning and morbidity (Ashman & Suttie, 1996). Because people with ID generally present some movement disorders, it is also important to understand that voluntary movement production is a concept of coordination (i.e., redundancy or abundance of movements; Latash, Kang, & Patterson, 2002). Balance and coordination impairments are most challenging to sensorimotor learning, and a deficit might limit the person’s autonomy in activities of daily living and in participating in recreational activities. Balance and coordination impairments are most evident among inactive

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individuals with ID (Carmeli, Bar-Yossef, Ariav, Levy, & Liebermann, 2008), and they might lead to general weakness, fatigability, abnormal movement synergies, loss of interjoint coordination, and incorrect timing of components within a movement pattern (Arnold et al., 2005). Different sensorimotor tasks involving integration of hand movements with visual information are routinely used for daily life activities. Sensorimotor interaction is necessary in many tasks, and in many cases, inaccurate grip force has been interpreted as a manifestation of impaired sensorimotor integration. Thus, when an individual’s hand cramps to lift an object, he or she grips it more forcefully than necessary (Serrien, Burgunder, & Wiesendanger, 2000). Clinically, the sensorimotor impairments in people with ID usually appear to be a problem of deficient coordination rather than of inaccurate force production. This impairment is more pronounced when an individual with ID is asked to perform an unfamiliar task or a task he or she does not have experience with, and it could be that this specific task is not preorganized well in his or her motor cortex (Hermsdörfer, Elias, Cole, Quaney, & Nowak, in press).

The goals of the current study were (1) to characterize sensorimotor deficits during coordination tests and (2) to identify if compensatory strategies are used by people with ID to achieve static standing and dynamic balance and, if so, (3) to identify what these strategies are.

**Materials and Methods**

**Participants**

A group of adults with mild ID was compared with an age-matched group in terms of specific motor tasks performed bilaterally.

The study population had lived at least 3 years in the residential care center, were familiar with their care staff, and required mild assistance for most of the daily activities. The residential care center environment is characterized by self-direction and sharing the needs, concerns, and expectations of the residents. The residents take part in the decision-making process that affects their lives (i.e., vocational duties, recreational activities, etc.).

After being referred to the study by the institutional health care professionals, only candidates that volunteered to participate were considered for the experimental trials. From a sample population of 216 permanent residents with ID, only 15 participants with mild ID were randomly included in the experimental group (10 women and 5 men; mean age = 44.4 ± 5.39 years, range = 40–50 years). Four inclusion criteria were used for selecting participants for the ID group:

1. Mild intellectual deficiency (IQ = 62–79) as diagnosed within 1 to 3 years after birth by IQ scores defined by the Wechsler Abbreviated Scale of Intelligence (Harcourt Assessment Inc., San Antonio; Hays, Reas, & Shaw, 2002).

2. Recognized ability to understand basic verbal communication.

3. Independence from personnel or from support services and devices.

4. Lived in the care centers for at least 3 years before being tested.

Candidates were excluded if they had a clinical history of neurological disease (e.g., Parkinson’s disease, stroke, Alzheimer’s disease, neuropathy, or brain surgery) or in the case of any peripheral neurological sign. In addition, candidates
were excluded if they showed any significant perceptual deficits (e.g., auditory and/or visual). None of the participants received narcotic medications at the time of the experiments.

Similarly, from 128 caregivers, health care professionals (such as physical and occupational therapists, nurses), and teachers who worked with the ID community, only 55 participants volunteered to be in the control group (30 women and 25 men; mean age = 44.1 ± 6.73 years, range = 29–53 years).

The study was approved by the Institutional Ethics Committee of Residential Care Centers under the administrative control of the Israeli Ministry of Welfare. Oral consent was obtained from participants, and written consent was obtained from their parents or guardians.

**Experimental Procedures**

Sensorimotor tests were performed in a quiet environment that minimized shifts of attention away from the experimental tasks. The examiner always provided first a standardized set of verbal instructions followed by a demonstration of the sensorimotor task. Before starting the tests, the participants underwent a familiarization trial with each test by performing each test one time with the left arm/leg and one time with the right arm/leg.

**Sensorimotor Tasks**

The reason for testing our hypothesis using the selected eight sensorimotor tasks was that the tasks included elements of hand–eye coordination (e.g., hand throwing to memorized visual targets, fast hand-finger actions in reaction to a visual event, grasping and transporting small objects, accurate shoulder-hand-finger movements). These tests have been shown to be reliable, were simple and easy to implement in field conditions, and were fairly close to real-life situations. Two tests were performed every other day.

**Test #1: Box and Blocks Test (B&B).** Performance of the B&B was carried out while the individuals faced toward a box (54 cm × 26 cm × 9 cm) located at the center of a “standard table” (i.e., seat height of ~47 cm). The box was divided into two equal compartments by a 15-cm-high dividing wall. The blocks consisted of 50 wooden cubes (2.5 cm³). To evaluate manual dexterity, participants were instructed to transport a maximal number of blocks from one side to the opposite side within 15 s, one block at a time (Mathiowetz, Volland, Kashman, & Weber, 1985). Individuals performed first with the preferred hand, and 3 min later, they performed with the opposite hand. Each participant performed two sets of trials with each hand (total of four sets performed in two stages). The B&B test was chosen because it is a robust test; it is known to yield high intrarater reliability scores (intrarater correlation coefficient [ICC] \( r = .92–.96 \) and interrater reliability coefficient [IRC] \( r = .78–.92; \) Desrosiers, Bravo, Hebert, Dutil, & Mercier, 1994).

**Test #2: 25-Grooved Pegboard Test (PegB).** The PegB test was designed to assess fine manual dexterity and hand–eye coordination (Schmidt, Oliveira, Rocha, & Abreu-Villaca, 2000). It consists of a wooden board with 25 holes. Performers were instructed to insert 25 cylindrical pegs (0.25-m diameter × 0.8-cm height) as
quickly as possible into the holes, one peg at a time. Performance time was continuously measured, even in the event that pegs were dropped down to the ground. The time to complete the task was measured twice for each hand. For such a test, reliability scores reported in the literature (Bornstein, 1986; Ruff & Parker, 1993; Desrosiers, Hebert, Bravo, & Dutil, 1995) are moderate to high (ICC $r = .69–.83$, $r = .65–.81$).

**Test #3: Stick Catching Test (StickC).** Reaction time (RT in ms) was assessed using a 2.5-cm wide × 100-cm long wooden ruler (0.1-cm nominal resolution), which was held vertically in the direction of the gravity vector. On release, performers were instructed to catch the ruler and prevent the free fall using a pinch-like grasping action. The measure of the distance obtained from the difference between the initial and final grasping heights was used as a measure of reaction time. According to Newton’s formula,

$$\text{flight time} = \sqrt{\frac{2 \cdot \text{distance}}{9.81 \, (m \cdot s^{-2})}}$$

and thus, the free fall distance could indeed provide a gross measure of visual RT because falling distance may be translated into the falling time (i.e., flight time), which is the time it would take the fingers to move after visually perceiving the onset of the fall of the ruler (Liebermann & Goodman, 2007). Such a method is just one among many ways of testing RT, but perhaps the simplest and most rudimentary. However, because our sample was randomly selected and enough data trials were collected, the current method was assumed to be a reliable way to assess RT. During the measurements, participants sat on a standard chair (which means that their performing arm was at $30^\circ$ flexion and $20^\circ$ abduction relative to a zero-arm configuration, as defined by the fully extended arm pointing forward). The elbow joint was positioned at $90^\circ$ flexion, and the forearm-wrist was maintained in a midtorsion position (between maximal supination and pronation). The examiner stood next to the performer and held the ruler at a zero starting point. At a random time, the examiner dropped the ruler and the performer attempted to grasp it. Six consecutive trials (three per hand) were carried out with a 15-s resting interval between measurements. RT measures provide robust descriptors of the ability to respond as fast as possible to an unexpected stimulus, with an intrarater validity or $r = .88–.94$ and a test–retest reliability of $r = .85–.96$ (Kauranen & Vanharanta, 1996).

**Test #4: Overhead Beanbag Throw (OverHBThrow).** The goal of this task was to throw a beanbag (500 g) over the homo-lateral shoulder in the direction of a hoop (0.75-m diameter) located at the center of a 1 m × 1 m gymnastic mat. The performer stood at a distance of 2 m facing away from the mat. Each hand performed 6 consecutive attempts (12 trials in total). After every trial, performers got immediate knowledge of results. A 0 through 3 scale was used to score the motor performance: 3 points were given for a throw that ended in the hoop, 2 points if the bag partially hit the hoop and later fell onto the mat, and 1 point if the bag landed anywhere on the mat without hitting the hoop. A zero score was given when the beanbag landed outside the mat. This arm-throwing test was assumed to test spatial orientation (Papaxanthis, Schieppati, Gentili, & Pozzo, 2002) accuracy and throwing
skill. Reported scores of reliability for ball-throwing tests are ICC $r = .58–.91$ and $r = .75–.92$ for test–retest sessions (de Greef, Dijkstra, Ottens, & Jansma, 2003). Mental rotation is among the different cognitive skills required for success in such a task. This has been specifically addressed in the early experiments of Shepard and colleagues (Shepard & Metzler, 1971). These authors showed that gradual mental rotation of an object increases the response time during the actual performance, whereas anticipatory mental rotation of the same object (before starting the performance) reduces the response time. Difficulty in mentally rotating objects might be one more expression of cognitive impairment. The overhead throwing task as performed here puts such a cognitive skill to the test.

Test #5a: Hitting a Tennis Ball, on a Cord Suspended From the Ceiling, With a Plastic Bat. The purpose of the tennis ball–hit test was to determine if the spatial and/or temporal context affected the coordination patterns of adults with ID in standing position. The second part of the test (Test #5b) aimed to investigate the behavior of center of pressure (COP) and body sway rate; thus, the participants stood on a Posture Scale Analyzer (PSA; Midot Ltd., Israel) while performing this task. The objective of this task was to hit a hanging ball with a bat (Rosey & Keller, 2004) with a straight arm. Instruments included a cord, tennis ball, and a plastic bat. The height of the tennis ball was adjusted to each participant so that the tennis ball was at nose height. To determine the distance of the ball to the participant, while standing, the participant put his/her arm in front of him/her, straight at the elbow, 90° at the shoulder. The ball needs to be at the middle of the bat. Instructions for the participant were, “Put your arm at the side of your body, and when you hear ‘go,’ you raise your arm and hit the ball from the side and bring the arm back to your body side.” The test was performed three times with the right arm and three times with the left arm, alternating right and left arm every time. Points were allocated as follows: missed the ball and cord, 0 points; touched the ball, 1 point; hit the ball: 2 points.

Test #5b: Hitting a Tennis Ball, on a Cord Suspended From the Ceiling, With a Plastic Bat While Standing on a Force Plate (see Posture Scale Analyzer section). The psychometric characteristics of this test are comparable to the previous one, and the procedure of this test was similar to Test #5a, but the participant was standing on a force plate, and following a “go” command, the participant hit the hanging ball. Yet, this test is also evaluating the feedforward mechanism in relation to the changes in center of pressure. The test was performed for 5 s and aimed to investigate (1) the feedforward mechanism used by the participant 2–3 s before hitting the ball and (2) to assess his or her ability to return to a quiet standing after hitting the ball.

Test #6: Throwing a Beanbag While Sitting on a Chair. This experiment was designed to investigate the varying conditions of contextual interference (Jarus & Goverover, 1999). The objective of this task was to throw a beanbag while sitting under a low contextual interference (blocked practice).

The instruments included a chair, beanbag (500 g), obstacle (height 50 cm, length 124.5 cm, width 2 cm), hoop (diameter 55 cm, width 2 cm, color blue), and polygon mat (80 cm by 80 cm). The distance from the chair to the obstacle was 2 m; the distance from the obstacle to the center of the hoop was 1 m. The hoop was
placed in the middle of a polygon mat. The obstacle was placed so the participant could not see the hoop while seated on the chair. In the beginning of the test, the participant stood in front of the chair and was asked to look where the hoop was so he knew where to throw the beanbag. Then, when he sat, he was asked to throw the beanbag in the middle of the hoop. In between throws he was allowed to stand up and check again where the hoop was so he knew in which direction to throw the beanbag. Each participant performed three acquisition trials with the right arm and three with the left arm, alternating right and left arm every time. Points were allocated as follows: missed completely/off the mat, 0 points; touching the polygon mat, 1 point; on the polygon mat, 2 points; on the hoop, 3 points; and 4 points if the beanbag fell in the middle of the hoop. With each throw, the first touch of the beanbag counts no matter whether it moves or jumps to another place after first contact.

**Test #7: Kicking a Ball Toward a Goal.** It has been proposed that because the participants never practiced any form of ball kick toward a goal, we should examine this skill ability by monitoring the performance of an ID individual’s ability to kick a ball with the dominant and nondominant leg (McLean & Tumilty, 1993). Thus, the purpose of this test was to examine the lower-limb coordination associated with practice of a ball kick.

The instruments included a basketball (500 g), goal/gate (measurements outside: width 80 cm, height 80 cm; measurements inside: width 77 cm, height 78 cm). The distance between the ball and the goal was 4.30 m.

Instructions for the participant were, “Kick the ball to the goal.”

The task was performed three times with the right leg and three times with the left leg, alternating between the right and left leg after each kick. The points were allocated as follows: missed goal, 0 points; on the post and outside, 1 point; on the post and in the goal, 2 points; in the goal, 3 points.

**Test #8: Balance Bar Forward Walking Test.** This test was conducted under the hypothesis that inactive people with ID might present poor cognitive-motor balance, and therefore, this should be investigated during walking on a narrow base of support. The instruments for this test included four wooden bars (length 99 cm, width 10 cm, height 3 cm) with connecting holes at the end and five connecting blocks (length 22 cm, width 7 cm) with pecks (length 3.3 cm). When the bars and the blocks were connected, the total length of the balance bar was 4 m. The bar was 10 cm above the ground. The participant was barefoot (without socks and shoes) and walked on the balance bar three times. At the beginning of the test, the participant started with 12 points. Points were subtracted when the participant lost his balance while walking on the balance bar. Losing balance could be either touching the ground with his feet or falling off the bar completely. Every time the participant walked on the balance bar it was counted how many times he lost his balance, and in the end, the points were subtracted from the 12 points he started with. The instructions for the participant were as follows, “Walk on the balance bar to the other side, step off the balance bar, and turn around. Step on the balance bar again and walk back, step off the balance bar, turn around and step on the balance bar again, and walk one more time to the other side.” The participant walked the balance bar three times.
The points were allocated as follows: without falling, 0 points were subtracted; foot on the ground, 1 point was subtracted; falling off, 2 points were subtracted; foot on the ground four times while walking one way, 12 points were subtracted; and three falls while walking one way, 12 points were subtracted. Each time a participant walked he or she could get a maximum of 4 points.

**Posture Scale Analyzer (PSA)**

Poor postural stability has been associated with ID, and clinicians rehabilitate balance deficits to prevent falls. Therefore, the purpose of using the PSA system was to examine static postural stability with the eyes open and closed and with arm pendulum movements.

The Posture Scale Analyzer (PSA) Midot-Medical Technology provides numerical and graphical and statistical data about the following: weight distribution between left and right, anterior and posterior; participant’s center of pressure (COP) during the test; and dynamic behavior of stability, sway rate, and sway direction. The PSA, based on four digital force plates, communicates with any computer with Windows.

In addition to Test #5b, all participants were examined under four different conditions in the following order: eyes open, eyes closed, eyes open with pendular movements following a metronome stimulus velocity of one beat every second, and lastly, eyes closed with pendular movements. All tests were performed with shoes off for 15 s.

**Statistical Analysis**

Analysis of data included multiple analyses of variance (ANOVAs) and Pearson correlations between variables. Correlation coefficients were calculated among the eight tests to determine the intercorrelation coefficients. Descriptive statistics were also calculated for relevant demographic variables, including the mean, standard deviation, and 95% confidence intervals for each dependent variable, with age and gender as grouping factors. A SPSS-v10 (SPSS Inc., Chicago, IL) package was used for the statistical assessment of the hypotheses. The confidence level was set at $p \leq .05$.

**Results**

Analyses of variance showed no differences in the clinical data of ID and control groups (Table 1). However, significant differences between the groups were found for the psychometrics characteristics (Tables 2–4).

All participants with ID successfully performed the eight sensorimotor tasks and the four balance tests using the PSA without needing to have a special accommodation for them. During the hitting the ball test and during the quiet standing test with eyes closed and with pendulum movements of the arms, the postural stability was maintained, accompanied by a relatively small sway rate as recorded by COP movements. In the ID group, the frontal plane movements were significantly larger ($p > .05$) than sagittal plane movements, whereas in the control group, these differences were unnoticed. The sway directions were inconsistent (i.e., posterior-anterior,
### Table 1  Participants’ Clinical Data

<table>
<thead>
<tr>
<th>Group</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Experimental group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>($n = 15$; women = 10, men = 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>44.4</td>
<td>5.5</td>
</tr>
<tr>
<td>body mass index</td>
<td>28.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Control group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>($n = 55$; women = 30, men = 25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>43.7</td>
<td>8.5</td>
</tr>
<tr>
<td>body mass index</td>
<td>28.2</td>
<td>3.9</td>
</tr>
</tbody>
</table>

### Table 2  Means and SD for the 8 Tests Compared by Gender

<table>
<thead>
<tr>
<th>Test</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men ($n = 5$)</td>
<td>Women ($n = 10$)</td>
</tr>
<tr>
<td>B&amp;B (number of blocks)</td>
<td>6 ± 2$^a$</td>
<td>6 ± 2$^a$</td>
</tr>
<tr>
<td>PegB (s)</td>
<td>59 ± 9$^a$</td>
<td>52 ± 7$^a$</td>
</tr>
<tr>
<td>StickC-RT (ms)</td>
<td>247$^a$</td>
<td>251$^a$</td>
</tr>
<tr>
<td>OverHBThrow (0–3 points)</td>
<td>1.2 ± 1$^a$</td>
<td>1.3 ± 1$^a$</td>
</tr>
<tr>
<td>BThrow in Sitting (0–4 points)</td>
<td>1.9 ± 1$^a$</td>
<td>2.1 ± 1$^a$</td>
</tr>
<tr>
<td>Tennis Ball Hit (0–2 points)</td>
<td>1.1 ± 0.9$^a$</td>
<td>1.2 ± 0.8$^a$</td>
</tr>
<tr>
<td>Ball Kicking (0–3 points)</td>
<td>1.8 ± 0.8$^a$</td>
<td>2 ± 0.8$^a$</td>
</tr>
<tr>
<td>Balance Bar Walking (–2 to 0 points)</td>
<td>−1.2 ± 0.3$^a$</td>
<td>−1.3 ± 0.2$^a$</td>
</tr>
</tbody>
</table>

$p < .05$ represents intergroup comparison.

### Table 3  Center of Pressure Distribution (Means in %)

<table>
<thead>
<tr>
<th>% Right</th>
<th>% Left</th>
<th>% Anterior</th>
<th>% Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant (intellectual disability)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>open eyes</td>
<td>50</td>
<td>50</td>
<td>52.33</td>
</tr>
<tr>
<td>closed eyes</td>
<td>52.66$^a$</td>
<td>47.33$^a$</td>
<td>40</td>
</tr>
<tr>
<td>ball hitting</td>
<td>55.67</td>
<td>44.33</td>
<td>41</td>
</tr>
<tr>
<td>Participant (control)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>open eyes</td>
<td>65</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>closed eyes</td>
<td>55</td>
<td>45</td>
<td>46.33</td>
</tr>
<tr>
<td>ball hitting</td>
<td>64.33</td>
<td>35.67</td>
<td>45.67</td>
</tr>
</tbody>
</table>

$p < .05$ represents intergroup comparison.
Repeated sessions showed strong correlations for the B&B test (ICC \( r = .92–.96 \)) and moderate correlations for the PegB test (ICC \( r = .69–.83 \)), stick catching test, and hitting a ball to assess reaction times (ICC \( r = .88–.94 \)) and accuracy (ICC \( r = .82–.86 \)). Strong correlations were found for the balance bar forward walking test (ICC \( r = .96–.92 \)), and moderate correlations were found for kicking a ball (ICC \( r = .62–.79 \)) and sway rate to assess balance stability.

Fair to good intercorrelations, with intercorrelations ranging \( r = .66–.78 \) (all significant at \( p < .05 \)), were observed between the eight tasks.

It is worth noting that given the similarities between the B&B and PegB tests, there was a strong relationship found (\( r = .96, p \leq .05 \)). This implies that one or the other might be considered redundant; therefore, only one of them should be implemented in the clinic.

Table 3 shows the percentage of center of pressure distributions between the right and left legs and between the anterior and posterior aspect of the foot. We can clearly see that during quiet standing, people with ID demonstrate a more symmetrical weight-bearing distribution than healthy control participants. In Table 4 we can see the plane’s standard deviations (SDs) of sway rate during three different standing positions. The higher the performance values, the greater the participant’s difficulty in maintaining stability. It can be noticed that with closed eyes and during the ball hitting tests, people with ID showed a significantly (\( p < .05 \)) less sway rate, probably exhibiting more stable standing.

### Discussion

In the current study, participants were tested under task constraints that resembled those in our previous study, but in all the sensorimotor tests, their performance was significantly poorer as compared with the performance of an age-matched group of controls. The most significant ID-related characteristic we observed concerned
the coordination of upper limbs. In addition, our current results showed that during quiet standing, a lesser sway rate occurred in the ID participants as compared with the control group. We did not specifically examine why the sway rates were practically decreased in the ID group, but we suggest that an inactive lifestyle, trunk stiffness, and fear of falling likely play a role.

Poor motor coordination might have functional impacts and might lead to exclusion from vocational and recreational activities and decreasing competence in activities of daily living (ADL). Our results suggest that people diagnosed as having mild ID perform poorly in manual tasks that require interactions between hand and leg motion and visual inputs.

**Postural Stability**

A preaging phenomenon among people with ID was previously reported, and among others, associated with locomotion deficits. Interestingly, increased postural stiffness with age has also been reported under different experimental conditions, including quiet stance (Collins & De Luca, 1995), reaching forward (Cavanaugh et al., 1999), and during gait (Hirasaki, Kubo, Nozawa, Matano, & Matsunaga, 1993). Because deterioration in motor performance under the previous constraints is one main characteristic of aging (Serrien, Swinnen, & Stelmach, 2000) aside from cognitive impairments (Span, Ridderinkhof, & van der Molen, 2004), we cannot preclude the possibility that the observed results might be an outcome of premature aging, characteristic of people with ID. It is possible that the decreased sway rate we observed in the ID group could be the result of a trunk-stiffening strategy. Maki and Fernie (1990) attributed low sway rate to an active stiffening strategy, which is apparently present under dynamic (high postural threat) conditions. In our experiment, it is possible that doing arm pendulum movements during quiet standing with the eyes closed might have been perceived as a more challenging situation for the ID participants than for the participants in the control group. The effects of trunk stiffness lead to decreasing COP. One possible reason for decreasing COP could be actively stiffening up because of a fear of falling. Persons who are afraid to fall often stiffen up in anticipation of postural perturbations (Maki & McIlroy, 1997; Maki, Holliday, & Topper, 1991; Carpenter et al., 2001). Another possible reason to stiffen up could be that the limits of stability are narrowed with aging (Murray, Seireg, & Sepic, 1975; Robinovitch & Cronin, 1999), and perception of this narrowing could force ID individuals to vigorously maintain their center of gravity within the safe range.

**Hand–Eye Coordination**

Tasks that are performed under perceptual or motor constraints, such as movement accuracy, reaction time, and speed of movement, might exacerbate the apparent deterioration of motor performance in people with ID. Thus, when a person with ID attempts to move and encounters all these impairments, the natural reaction is to compensate with the available motor strategies. A negative consequence might be the lack of limb-girdle mobility, which might limit the normal kinematics of upper- and lower-limb movement. According to Bornstein (1986), motor control is associated with “optimal synergies” or “co-ordinative structures.” Therefore, the
nervous system uses certain available strategies to accomplish a specific motor task, and facing a new task results in the reorganization of the coordinative structure. Difficulties in performing hand–eye coordination tasks might underlie some of the difficulties of adults with ID during their ADLs. An expression of such cognitive impairment might be a generally poor motor performance. The relationship between ID and lack of success in basic motor skills has only attracted limited attention, particularly concerning balance and sensorimotor coordination in people with ID (Kelly & Jessop, 1996). The visual occlusion paradigm during motor performance has been widely used to assess the effect of continuous or intermittent feedback on the execution of movement. Occlusion of visual input might lead to the use of internal representations of the environment. An internal visual representation could indeed be used to activate and modulate previously acquired motor plans with little or no feedback. Do individuals with ID lack this ability during aiming tasks? The findings here show that this might be the case, and such a possibility is supported by earlier literature (Elliott, 1990; Elliott, Chua, & Pollock, 1994). The beanbag throw tests in our experimental trials were carried out backward and forward to a previously seen target. Thus, the tests posed a cognitive challenge to our participants with mild ID because they required the ability to perform an accurate task without visual perception of the location of the target. We showed that lack of continuous visual input affected the performance of people with mild ID. Although the beanbag throwing task might be seemingly simple, the sensorimotor ability required for its performance is the ability to locate objects relative to rotated body coordinates within a fixed reference frame. This might be a challenge for individuals with ID. Accurate backward throws involve the transformation of joint coordinates that define the appropriate arm–hand configuration into spatial coordinates of the mentally visualized target. Such a task involves also an adjustment of motor commands. During a normal throwing task, arm extension might be appropriate because the performer faces the target. However, when the performer faces in the opposite direction (a 180° rotation of the body), a backward throwing movement is required because the target is located behind, and thus, arm flexion is the appropriate action. Participants in the current study often failed to make such a coordinate transformation in the correct target direction. From our study we identified major components of motor disorders in ID that included longer reaction times, disproportionate forces in coordination tests, and the lack of adaptation to changes in sensory information such as in the beanbag throw. Moreover, Spencer et al. (2005) assumed that sensorimotor malfunctions originate from impairment of a subsystem within the general system of movement production. One function of this subsystem is likely to be information processing, including decision making. Therefore, the central nervous system in people with ID might be reluctant to produce motor commands leading to accurate movements to have movement corrections when asked to produce specific sensorimotor tasks. People with ID have “lack of ability” or “luck of skill” in preprogrammed postural reactions during sensorimotor tasks (Shumway-Cook & Woollacott, 1985). Onset latencies for postural reactions were considerably longer in people with ID (Aruin, Almeida, & Latash, 1996), as well as muscle coactivation, representing the consequence of an impaired mechanism of preprogramming; thus, the preprogramming increases the activity of a “wrong” muscle group.
The major limitation of our study is the lack of standardized measures of functional performance for this unique population. There is a large heterogeneity in assessment methods in studies, which makes comparison between studies difficult. Furthermore, in the current study, only psychometric tests were used and no measure of cardiovascular endurance was included. Because most subjects had difficulties with walking or running, measuring cardiovascular endurance would have been difficult in our study population. Owing to the large imbalance between women and men in our study population, which is common in this age category, the results and conclusions regarding the comparison of the sexes must be interpreted with care.

**Clinical Relevance**

Assessing perceptual-motor coordination might contribute to understanding the nature of ID because poor hand–eye coordination is an expression of ID (Sachdev, Wen, Christensen, & Jorm, 2005). In this regard, the beanbag throw tests pose a challenge because they might be associated with the mental rotation of a previously acquired visual representation of the environment. Such a motor task might enable discrimination among individuals at different stages of the rehabilitation process because it emphasizes critical cognitive elements related to success in the performance of ADL. Increased postural stiffness resulting from aging, limits of stability, or fear of falling requires an accurate rehabilitation plan.

**Conclusions**

Evaluation of motor coordination and motor balance in people with ID remains a challenge because many factors might interact with the different tests used. Motor coordination and balance assessments might allow for the designing of early rehabilitation programs specific to the individuals. Rehabilitation protocols should thus include specific motor tests as part of the common cognitive assessments.

**Acknowledgments**

The authors wish to thank Israel rehabilitation for bestowing the annual Prof. Razin Raffi prize of 2008 on our group.

**References**


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