Bilateral Motor Coordination in 5- to 9-Year-Old Children: A Pilot Study

Livia C. Magalhaes, Jane A. Koomar, Sharon A. Cermak

Key Words: coordination evaluation • motor activity • sensory integration

The purpose of this study was to collect normative data on and to assess the clinical usefulness of scales designed to measure the quality of children's ability to perform three bilateral motor coordination tasks: jumping jacks, symmetrical stride jumps, and reciprocal stride jumps. One hundred children, aged 5 to 9 years, were tested according to the scales developed for this study. Results indicated that scores tended to increase with age and that sex differences were not significant. Jumping jacks were found to be the most reliable and the easiest of the three tasks. Reciprocal stride jumps were the most difficult. Quality of performance was assessed, and the number of jumps in a 30-sec trial was recorded for each age. The data from this study may be useful in comparing the performance of children with motor deficits to the performance of normal children of the same age.

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ordination has received little attention (Williams, 1983). Bilateral motor coordination refers to the ability to use both sides of the body in an integrated and skillful manner (Williams). Ayres (1972) said that the process of integration of vestibular and proprioceptive sensations and the efficiency of interhemispheral connections are the bases for good bilateral integration of both sides of the body.

The development of bilateral motor coordination begins early in life and is the basis for further motor development (Berk & DeGangi, 1983; Kauffman, 1983). Although there are differences among individuals, the acquisition of control over the use of the extremities follows a developmental sequence that usually starts with control over bilateral, symmetrical movements (e.g., pat-a-cake), then moves to homolateral or unilateral movements (e.g., unilateral reaching), and finally proceeds to reciprocal movements of the extremities and skilled bilateral function (e.g., crawling) (Williams, 1983). As the child's postural abilities improve, elements of this developmental sequence recur during the acquisition of new and more complex bilateral skills.

Although Williams (1983) suggested that a 6-year-old child should show good mastery of all developmental phases of bilateral motor coordination, there is some evidence that complete mastery of all phases is achieved at later ages. According to Kauffman (1983), good performance on alternate foot tapping and on jumping jacks should be expected at the age of 7 years, and on alternate hops (two right, two left or two right, one left), at the age of 8 years. In a study in which 6- to 12-year-olds were tested on a variety of motor tasks (Hughes & Riley, 1981), a task requiring the children to perform sequential adduction and abduction of the lower limbs while jumping in place was dropped for 6-year-olds because it was found to be too difficult. However, for older children, the same task was found to be valuable in determining motor problems. These findings suggest that refinements in some aspects of bilateral coordination occur after the age of 6 years. They also suggest that although simple motor tasks can be used to detect motor dysfunction in children, the tasks must be considered within a developmental context.

Activities such as those mentioned above, besides involving bilateral motor coordination, require the ability to plan movements, especially while the tasks are being learned. Motor planning, or praxis, is the ability to plan and execute skilled or nonhabitual motor tasks (Ayres, 1972). Therapists assessing bilateral motor coordination in children can observe coordination as well as the strategies children use to learn the new movements.

The developmental sequences of walking, running, vertical jumping, skipping, and other gross motor activities and exercises recommended for children have been described (Gesell, 1946; Williams, 1983). However, although the activity of jumping jacks is familiar to many children and is mentioned frequently in motor programs for children, the developmental components of jumping jacks have not been studied. There are no references to age expectations for accurate performance of this motor task or to the factors that contribute to acquisition of this skill.

Age is evidently a critical factor in the acquisition of motor skills in children. Some authors have also suggested there might be sex differences in the rate of motor maturation (Waber, 1979), but this idea has been contested (Thomas & French, 1985). Studies of motor control should address this question.

Several studies have shown that children with developmental delay tend to have difficulties on bilateral motor tasks. Ayres (1972, 1979) found that children with developmental dyspraxia and vestibular-bilateral motor coordination disorders tend to present poor bilateral motor coordination. According to Cratty (1980), an inability to integrate body parts can be manifested by difficulties in performing jumping jacks. He stated that clumsy children tend to find jumping jacks particularly difficult because of their inability to coordinate the simultaneous movements of the arms and legs. Cratty recommended that the evaluation of these children not only depend on standardized tests of upper body or lower body bilateral coordination but also include complex tasks like jumping jacks.

Observation of children's performance on jumping jacks and two other jumping tasks, the symmetrical stride jump and the reciprocal stride jump, involving respectively, homolateral and contralateral control of the arms and legs, could help therapists understand the development of praxis and bilateral motor coordination. Before these motor tasks can be used as assessment tools, it is necessary to determine how normal children perform at different ages and whether there are sex differences in performance.

We therefore developed three scales to measure performance of jumping jacks, symmetrical stride jumps, and reciprocal stride jumps. On the basis of these scales, the following hypotheses were tested:

1. There will not be a significant sex effect on any of the tasks.
2. There will be a significant age effect such that older children will have significantly higher scores than younger children on each of the three scales.
3. There will be a significant task effect such that the scores on the jumping-jacks scale will be significantly higher than the scores on the other two scales, and the scores on the sym-
metrical-stride-jump scale will be significantly higher than the scores on the reciprocal-stride-jump scale.

4. There will be a significant age-task interaction such that older children will present significantly fewer differences in scores between the three scales than will younger children.

Method
Subjects
The subjects were 100 right-handed, normal boys and girls, with 20 subjects, 10 boys and 10 girls, at each of the following five age levels: 5, 6, 7, 8, and 9 years. All subjects were selected from two public elementary schools in the Boston area. This sample primarily represented the lower middle class socioeconomic level and consisted of 83% Caucasian children and 17% minority children. Information provided by the classroom teacher and school records was used to select the 6- to 9-year-old children according to the following criteria: (a) no physical or motor deficits, (b) normal hearing and corrected vision, (c) no language or learning disorders, (d) no illness lasting more than 3 months immediately before or during school attendance, (e) no acceleration or repetition of a grade, (f) no failure in a current subject, (g) normal intelligence as measured by a group intelligence test, (h) right-handedness for writing, and (i) no history of educational remediation. Inclusion criteria for 5-year-olds were the same with one exception: school achievement was measured by age-appropriate performance on a preschool screening test, as reported by the teacher.

Instrumentation
To develop the scales to assess the three motor tasks, normal children of various ages were videotaped performing the tasks. The tape was shown to other experienced therapists and occupational therapy graduate students to determine what they considered to be the most important characteristics of the performances. These data were summarized and organized on three 5-point scales by the first author. These scales were then reviewed by experts, and a pilot study involving 10 children, 5 to 10 years of age, was conducted to establish content validity. The final format of the jumping-jacks scale is shown in Figure 1.

The three scales were identical in format; differences in the scoring criteria reflected variations in motor competencies involved in each of the three tasks. For each task there were two phases:

1. Learning phase: The examiner explained and demonstrated the specific motor task. The three items in this phase—(a) response to instruction, (b) initiation of sequences, and (c) coordination of arms and legs—were de-

<table>
<thead>
<tr>
<th>Learning Phase</th>
<th>Score</th>
<th>Performance Phase</th>
<th>Score</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>5</td>
<td>Needs second demonstration</td>
<td>3</td>
<td>Needs verbal and physical structure</td>
</tr>
<tr>
<td>Response to instruction</td>
<td>Spontaneous</td>
<td>Needs verbal structure</td>
<td>Performs only with examiner</td>
<td>2</td>
</tr>
<tr>
<td>Initiation of sequences</td>
<td>Smooth and uninterrupted, able to do five in a row</td>
<td>Hesitates or interrupts between sequences</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Coordination of arms and legs</td>
<td>Rhythmic, full pattern</td>
<td>Reverses pattern after two or three jumps</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of full patterns in 10 sec</td>
<td>≥10</td>
<td>6 to 4</td>
<td>3 to 1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Quality of performance</td>
<td>Rhythmic, uninterrupted full pattern</td>
<td>Has two or more interruptions or reverses after four to five jumps with no correction</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Learning phase score Performance phase score Total score

Figure 1. Jumping-jacks scale and score sheet.
signed to evaluate aspects of the strategies a child uses to learn the task and the quality of initial performance. Each item was scored on a scale from 1 to 5 (with 1 being the lowest and 5 the highest score) and reflected the child's best performance.

2. Performance phase: The examiner asked the child to perform the task for 10 seconds. The number of repetitions and the quality of performance were scored on two additional items: (a) number of full patterns in 10 seconds and (b) quality of performance. The performance on each item was scored on a scale from 1 (lowest) to 5 (highest).

For each scale, a total score was computed by adding the score obtained on each test item. Partial scores for the learning and performance phases were obtained in the same way. The examiner also counted the number of correct jumps completed during the performance phase.

Interrater reliability was obtained for the three scales before the actual testing. A videotape showing the performances of 5 normal children on the scales was used by the first author to teach the scoring criteria to another rater, an occupational therapist who was a graduate student. After being trained, the two therapists independently scored the actual performance of 5 other normal children, 5 to 9 years of age. The intraclass correlation (Francis, 1986) for the two raters was \( r = .99 \) for the jumping-jacks and symmetrical-stride-jump scales and \( r = 1.00 \) (a perfect correlation) for the reciprocal-stride-jump scale.

Test-retest reliability was established by twice testing a group of 10 children, aged 7 and 8 years, on all three measures, with 2 weeks between each test. The Pearson correlation coefficient for the total scores was \( r = .82 \) for the jumping-jacks scale, \( r = .65 \) for the symmetrical-stride-jump scale, and \( r = .73 \) for the reciprocal-stride-jump scale. Criterion-related validity and construct validity were not assessed.

Procedure
After obtaining parental consent, we tested each child individually in the school gymnasium of their respective schools. Standard 19-mm masking tape was used to draw a 90 X 130 cm rectangle on the floor, which indicated where the test was going to take place. The center of the rectangle was marked by a 30 X 30 cm cross, which indicated the starting position for each task. Of the 100 subjects, all but 3 jumped within the limit line. Because only 3 subjects stepped on the limit line, this scale item was considered nonsignificant and dropped from the scales.

During test procedures the examiner stood approximately 2 m away from and facing the child. From this position the examiner gave instructions and recorded each child's performance on the test sheet. All children wore shoes during testing. Each child was given the tests in the following order:

1. Jumping jacks: This task consisted of rhythmic jumping jacks with simultaneous abduction of straight arms above the head and legs to the sides and return to initial position.
2. Symmetrical stride jump: Right arm and leg were placed forward; left arm and leg, back. This task consisted of jumping in place in a rhythmical pattern while reversing the position of arms and legs for each jump.
3. Reciprocal stride jump: Right arm and left leg were placed forward; left arm and right leg, back. This task consisted of jumping in place in a rhythmical pattern while reversing the position of arms and legs for each jump.

An electronic timer was used to measure the 10-second periods in the Performance phase. We found during the pilot study that this timer was more useful than a regular stopwatch because it featured a beep that allowed for more precise measurement. It also freed the tester to concentrate only on the child's performance.

The whole procedure took about 5 to 10 minutes for each child, depending on the amount of instruction needed. Breaks were allowed between tasks according to each child's needs. Younger children tended to show signs of fatigue, whereas most of the 8- and 9-year-old children performed the three tasks without intervals of rest.

Results
A 5 X 2 X 3 (Age X Sex X Task) repeated measures analysis of variance (ANOVA) was performed on the total score of the three jumping tasks. Results showed that, overall, sex was not significant, \( F(1, 90) = 2.85, p = .09 \); age was significant, \( F(4, 90) = 17.66, p < .001 \); task was significant, \( F(2, 180) = 115.76, p < .001 \); and none of the interactions were significant. With the use of the Duncan multiple comparison procedure, significant differences \((p < .05)\) were found between 5-year-olds and 7-, 8-, and 9-year-olds, and between 6-year-olds and 8- and 9-year-olds. The same procedure also showed significant differences between the three tasks.

Separate ANOVAs were also performed for the learning and performance phases. A 5 X 2 X 3 (Age X Sex X Task) repeated measures ANOVA on the learning phase scores indicated that sex was not significant, \( F(1, 90) = 1.64, p = .20 \); age was significant, \( F(4, 90) = 18.51, p < .001 \); task was significant, \( F(2, 180) = 82.46, p < .001 \); and none of the age-task interactions were significant.
The Age X Sex repeated measures ANOVA on the performance phase scores indicated that sex was not significant, $F(1, 90) = 1.80, p = .054$; age was significant, $F(4, 90) = 13.23, p < .001$; task was significant, $F(2, 180) = 86.47, p < .001$; and age-task interaction was significant, $F(8, 180) = 3.70, p < .001$. No other interactions were significant. The Duncan multiple range test indicated that at each age sex was a significant difference ($p < .05$) between reciprocal stride jumps and jumping jacks and between reciprocal stride jumps and symmetrical stride jumps. However, there was no significant difference between symmetrical stride jumps and jumping jacks at any age.

Because sex differences did not significantly affect performance, data for boys and girls were combined. Table 1 presents the means and standard deviations for the total score and the learning, and performance phase scores as a function of age for each of the three jumping tasks.

Three $5 \times 2$ (Age X Sex) ANOVAs, one for each task, were conducted for the actual number of correct jumps completed in 10 seconds on the performance phase. Table 2 presents the means and standard deviations for the actual number of jumps in 10 seconds as a function of age and task. For jumping jacks, sex was not significant, $F(1, 90) = 0.48, p = .491$; age was significant, $F(4, 90) = 20.55, p < .001$; and age-task interaction was not significant. With the use of the Duncan multiple comparison procedure, differences ($p < .05$) in the number of jumping jacks performed were found between the 5-year-olds and the 6-, 7-, 8-, and 9-year-olds, between the 6-year-olds and the 7-, 8-, and 9-year-olds, and between the 7-year-olds and the 9-year-olds. For symmetrical stride jumps, sex was significant, $F(1, 90) = 5.78, p < .05$, with girls doing better than boys; age was significant, $F(4, 90) = 9.94, p < .001$; and age-task interaction was not significant. The Duncan procedure indicated that the source of difference in age ($p < .05$) was between 5-year-olds and 7-, 8-, and 9-year-olds and between 6-year-olds and 8- and 9-year-olds. The ANOVA performed on the number of reciprocal jumps indicated that sex was not significant, $F(1, 90) = .83, p = .366$; age was not significant, $F(4, 90) = 1.57, p = .18$; and age-task interaction was not significant.

**Table 1**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Jumping Jacks</th>
<th>Symmetrical Jump</th>
<th>Reciprocal Jump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>$\bar{X}$</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Learning</td>
<td>Performance</td>
<td>5.0</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>15.7</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>11.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Learning</td>
<td>Performance</td>
<td>6.6</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>18.4</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>14.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Learning</td>
<td>Performance</td>
<td>8.6</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23.1</td>
<td>2.8</td>
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<td></td>
<td>8</td>
<td>14.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Learning</td>
<td>Performance</td>
<td>9.6</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24.4</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>14.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Learning</td>
<td>Performance</td>
<td>9.7</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

$^a n = 20$ for each age group.

**Table 2**

<table>
<thead>
<tr>
<th>Task</th>
<th>Jumping Jacks</th>
<th>Symmetrical Jump</th>
<th>Reciprocal Jump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>$\bar{X}$</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>3.9</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.9</td>
<td>4.5</td>
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<td>3.9</td>
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<td></td>
<td>8</td>
<td>11.8</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>12.9</td>
<td>3.2</td>
</tr>
</tbody>
</table>

$^a n = 20$ for each age group.

**Discussion**

According to the results, the three jumping tasks, as measured by total scores, present increasing levels of difficulty, and the ability to learn the tasks improves with age. As hypothesized, jumping jacks was the easiest task, but consistent, spontaneous, correct performance should not be expected before the age of 7 years. This finding is in agreement with Kaufman's (1983) expectations. The symmetrical stride jump was the second most difficult task, in which the children's performance was not consistent and spontaneous until the age of 9 years, with only 50% of the 9-year-olds obtaining a perfect or near-perfect score (23 points or above).

As expected, the reciprocal stride jump was the most difficult task, in which only 15% of the 9-year-olds (3 children) obtained a near-perfect score. The scores obtained on the reciprocal-stride-jump scale (see Table 1), show that in the learning phase the scores increased consistently with age, indicating that the older children needed less instruction to perform the task correctly than the younger children. Although the older children learned the tasks faster, their scores in the performance phase, and consequently, their total scores, did not improve with age. An explanation for this lack of improvement might be the fact that during test procedures the 9-year-olds tended to get confused when being timed. During the
performance phase, 40% of the 9-year-olds reversed the pattern on the first jump and did the easier symmetrical pattern instead of the reciprocal one. These children did not seem to notice they were doing the wrong pattern and tended to perform a more automatic pattern when under time constraints. The results obtained on the reciprocal-stride-jump scale suggest that the neuromotor mechanisms underlying the ability to do this type of motor task might still be under development at the age of 9 years.

Sex differences in performance were not evidenced on any of the jumping tasks, except on the symmetrical-stride-jump scale, where girls were faster and therefore performed more jumps. This difference may be due to the small sample size or, perhaps, to the practice of bilateral motor tasks, such as clapping games or jump rope, which are more commonly played by girls. This finding is consistent with Thomas and French's (1985) proposition that there are no biological gender differences on specific motor tasks before puberty, and that such differences, when they are observed, are thought to be induced by environmental expectations.

The results of the present study indicate that the scales developed may be useful tools in assessing children's ability to perform jumping jacks, symmetrical stride jumps, and reciprocal stride jumps. Test procedures can be administered in less than 10 minutes, the scoring criteria are easy to learn, and raters can be trained to score in a reliable way, as indicated by the high interrater reliability indexes.

Although the scales present some characteristics that are highly desirable as screening assessments for motor dysfunction, their test-retest reliability and the age range to which they apply pose limitations on their use. The test-retest reliability coefficients for the symmetrical-stride-jump and reciprocal-stride-jump scales indicate only a moderate degree of reproducibility. Two factors may have contributed to lower correlations. Some subjects, frustrated by their poor performance on the first test, and others, challenged to improve their performance, reported they had practiced the symmetrical and reciprocal stride jumps between the two test administrations. Although this practice effect may have lowered the test-retest reliability on both symmetrical and reciprocal stride jumps, it is not clear why the test-retest reliability was even lower for the symmetrical-stride-jump scale. The scoring criteria on this scale may need minor revisions. It is also reasonable to expect that some children may have benefited from practice during the learning phase of testing and that they therefore received higher overall scores when tested the second time.

None of the children reported having practiced jumping jacks between test sessions, perhaps because this was an activity more familiar to them than stride jumps. The test-retest reliability coefficient for the jumping-jacks scale was higher than for the other two tasks, thus indicating good reproducibility. Therefore, jumping jacks, as measured on this scale, may be the most useful tool for the assessment of bilateral motor coordination.

Considering the age level at which groups of children gain proficiency in each of the three jumping tasks, it seems reasonable to use the jumping-jacks and symmetrical-stride-jump scales with children aged 5 years and older. The reciprocal-stride-jump scale does not seem appropriate for children younger than 7 years of age because approximately 50% of the 5- and 6-year-old children failed to learn the task. This task also proved to be difficult for 9-year-olds. Therefore, the use of this scale as a screening measure should be limited until further research is done to identify the age at which reciprocal stride jumps can be developed as a skill.

It would be interesting to study further whether these scales can differentiate between children who have motor deficits (e.g., sensory integration dysfunction) and children who do not have these deficits. Another component to investigate is the contribution of praxis to the performance of these tasks.

**Summary**

Normal children aged 5 to 9 years, 10 boys and 10 girls at each age level, were tested on their ability to do jumping jacks, symmetrical stride jumps, and reciprocal stride jumps. The children's performance on each of the three tasks was scored according to scales developed by the first author, and the use of these scales to assess motor skill development in children was discussed. There were no sex differences on the tasks. However, there were significant differences in the performance on each task according to the child's age level. Jumping jacks were shown to be the easiest task, performed well by children aged 7 years and older. The symmetrical stride jump was an intermediate task that most of the 9-year-old children performed well. The children's performance on the reciprocal-stride-jump scale was somewhat variable, and the task appeared to be too difficult for the majority of the children tested.

In conclusion it can be said that the jumping-jacks scale is useful as a screening tool in the assessment of bilateral motor coordination in children. The symmetrical-stride-jump scale also is a useful measure; however, results indicate that it is not as reliable as the jumping-jacks scale.

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References


