Locomotor Tests Predict Community Mobility in Children and Youth With Cerebral Palsy

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Ambulatory children and youth with cerebral palsy have limitations in locomotor capacities and in community mobility. The ability of three locomotor tests to predict community mobility in this population (N = 49, 27 boys, 6–16 years old) was examined. The tests were a level ground walking test, the 6-min-Walk-Test (6MWT), and two tests of advanced locomotor capacities, the 10-meter-Shuttle-Run-Test (10mSRT) and the Timed-Up-and-Down-Stairs-Test (TUDS). Community mobility was measured with the Assessment of Life Habits mobility category. After age and height were controlled, regression analysis identified 10mSRT and TUDS values as significant predictors of community mobility. They explained about 40% of the variance in the Life Habits mobility category scores. The 10mSRT was the strongest predictor (standardized Beta coefficient = 0.48, p = 0.002). The 6MWT was not a significant predictor. Thus, advanced locomotor capacity tests may be better predictors of community mobility in this population than level ground walking tests.

Keywords: aerobic capacity, six-minute walk test, stairs

Cerebral palsy (CP) is defined as “a group of permanent disorders of the development of movement and posture” (Rosenbaum et al., 2007). In developed countries, about one child in 500 has this condition (Paneth, Hong, & Korzeniewski, 2006). Persons with CP who walk without support make up more than half (59.3%) of the population of persons with CP (Howard et al., 2005). Although this subgroup is usually integrated into inclusive schools (Majnemer et al., 2008),
they have limitations in more advanced locomotor capacities (Rosenbaum et al., 2002). Overall, children and youth with CP are also less involved in physical or skill-based community activities than are their typically developing peers (Imms, Reilly, Carlin, & Dodd, 2008; Law et al., 2006; Majnemer et al., 2008). In addition, their level of walking proficiency is strongly and positively related to their level of habitual physical activity (Maltais, Pierrynowski, Galea, & Bar-Or, 2005). Locomotor capacity tests appropriate for children and youth with CP who walk without support, and relevant to their mobility in the community, are therefore important evaluation tools. These types of tests can be used by educators, coaches, and clinicians to evaluate the effects of exercise programs or other interventions. They can also be used by researchers involved in large scale studies, where it may not be feasible to use laboratory-based testing.

Only one study by Lepage, Noreau, and Bernard (1998) has assessed the relationship between locomotor capacity test scores and community mobility. Lepage et al. (1998) measured locomotor capacities using a short distance, 45 m, level ground walking test and the time to walk up and down a flight of stairs. They assessed community mobility using the mobility category of the Life-Habits (Life-H) questionnaire. The correlations ($r$) between the mobility category scores and the stair and walking test values were .82 and .60, respectively. Lepage et al. (1998) concluded that the stair locomotion values were more closely related to mobility category scores than the walking test values because stair locomotion skills are the better indicator of overall motor capacity.

Recent information suggests, however, that level ground locomotor capacities should be measured in children and youth with CP using longer distance tests rather than a short distance test as done by Lepage et al. (1998). Pirpiris et al. (2003) evaluated walking speed in children and youth with various neuromuscular conditions, including CP. The average walking speed during a short distance 10-m walk ($M = 1.00 \text{ m·s}^{-1}, SD = 0.30$) was significantly higher than the speed during a longer 10-min walk ($M = 0.87 \text{ m·s}^{-1}, SD = 0.24$). The researchers concluded that short distance walking tests may not be an appropriate measure of the walking ability needed for community mobility (Pirpiris et al., 2003).

Furthermore, Thompson et al. (2008) evaluated the test-retest reliability of level ground walking tests in children and youth with CP who walk without support. Two tests were assessed: the short distance, 10-m walk test and the longer distance, six-minute walk test (6MWT; Thompson et al., 2008). For both tests, reliability was quantified using an intraclass correlation coefficient (ICC). More specifically, an ICC (2, 1) was used (Shrout & Fleiss, 1979), based on a two-way random, single measures model (Thompson et al., 2008). For the 10-m test, the ICC (2, 1) was ≤ .70. This was considered to be unacceptable test-retest reliability by the authors (Thompson et al., 2008). The 6MWT, on the other hand, was found to have acceptable test-retest reliability, as the ICC (2, 1) was ≥ .91 (Thompson et al., 2008). The test-retest reliability in this population of another longer distance, level ground locomotor capacity test, the 10-m Shuttle Run Test (10mSRT), has also been evaluated (Verschuren, Takken, Ketelaar, Gorter, & Helders, 2006). This test could be considered to evaluate more advanced locomotor capacities than the 6MWT because the child or youth must run, stop, and turn quickly as well as walk while performing the test (Verschuren et al., 2006). A two-way, mixed, single measures, absolute agreement model was used to evaluate the reliability of the 10mSRT (Verschuren et al., 2006; O. Verschuren,
personal communication, September 29, 2011). The ICC (3, 1) was ≥ .97, which was considered to be acceptable reliability (Verschuren et al., 2006). In addition, a recent expert consensus exercise (Verschuren et al., 2011) concluded that the 6MWT and the 10mSRT are the only published level ground locomotor tests appropriate for children and youth with CP who walk without support. No other tests have published acceptable psychometric properties for this group. In light of these recent studies by Pirpiris et al. (2003), Thompson et al. (2008), and Verschuren et al. (2006), the relationship between locomotor capacities and community mobility in children and youth with CP who walk without support warrants a new investigation with the 6MWT and the 10mSRT as well as with a stair locomotion test.

At the time of the work by Lepage et al. (1998), there were no published studies on the psychometric properties of stair locomotion tests for children and youth with CP. Since then, the Timed-Up-And-Down-Stairs test has been developed (Zaino, Marchese, & Westcott, 2004). Like the 6MWT and the 10mSRT, the TUDS is a reliable test of locomotor capacity in children and youth with CP. Zaino et al. (2004) evaluated the within-day test-retest reliability (2 hr between the tests) of the TUDS. They used a two-way random, single measures model with absolute agreement (S.L. Westcott, personal communication, September 27, 2011). The reported ICC (2, 1) was .94. Interrater reliability (absolute agreement) was also high with an ICC (2, 1) of .99.

The purpose of this present study was therefore to examine the ability of these three specific tests, the 6MWT, the 10mSRT, and the TUDS, to predict community mobility in children and youth with CP who walk without support. The 6MWT evaluated simple level ground walking. The 10mSRT and the TUDS evaluated more advanced locomotor capacities. Performance in community mobility was quantified using the mobility category of the pediatric (child) version of the Assessment of Life Habits (LIFE-HC; Noreau et al., 2007). Height and age were controlled for in the statistical analysis as they are personal factors not necessarily related to locomotor capacity limitations (Geiger et al., 2007; Verschuren, Bloemen, Kruitwagen, & Takken, 2010; Zaino et al., 2004).

Method

Participants

Forty-nine participants (convenience sample) were recruited from two pediatric rehabilitation centers in the Quebec City region in Canada. The inclusion criteria were (a) diagnosis of CP; (b) receiving physical therapy services at a children’s rehabilitation center; (c) ambulatory without support, Gross Motor Function Classification System (GMFCS; Palisano et al., 1997) level I or II; (d) 6–16 years old; and (e) community school attendance. Participants were excluded if (a) they had undergone orthopedic or neurological surgery within six months before the study or (b) they had received Botulinum toxin A injections to the lower limb muscles within three months before the study. These factors were chosen because they can temporarily affect locomotor capacities. The study was approved by the institutional review board of the Quebec Rehabilitation Institute. Parents provided written informed consent and the participants, written informed assent to participate in the study. Participant characteristics are summarized in Table 1.
Table 1  Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>M (SD) (N = 49)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>10.67 (2.83)</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>142.20 (17.40)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>34.47 (13.28)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
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</tr>
<tr>
<td>Male</td>
<td>27</td>
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</tr>
<tr>
<td>Female</td>
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</tr>
<tr>
<td>GMFCS</td>
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<tr>
<td>Level I</td>
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<tr>
<td>Level II</td>
<td>7</td>
<td></td>
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<tr>
<td>Type of CP</td>
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<tr>
<td>Diplegia</td>
<td>18</td>
<td></td>
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<tr>
<td>Hemiplegia</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Quadriplegia</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Ataxia</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

*Note. GMFCS = Gross Motor Function Classification System; CP = cerebral palsy.*

Measures

The 6-min Walk Test. The 6MWT measures level ground walking capacity (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, 2002). It is scored as the maximum distance that the person can walk in 6 min. The test shows discriminant validity for children and youth with CP. The distance walked is greater for those who walk without support, compared with those who walk with support (Thompson et al., 2008). As noted in the introduction, children and youth with CP can also perform the test reliably from day to day without a practice test (Thompson et al., 2008). The evaluator does not influence the results of the test (Thompson et al., 2008).

The 10-m Shuttle Run Test. The 10mSRT is a locomotor-based walking and running test of maximal aerobic capacity that was designed for children and youth with CP who walk without support (Verschuren et al., 2006). It scored, in this case, as the maximum speed obtained at the end of the test (Verschuren et al., 2006). The 10mSRT shows concurrent validity, $r = .96$, with maximal oxygen uptake (Verschuren et al., 2006). As stated in the introduction, test results are reliable from day to day without a practice test (Verschuren et al., 2006). It is assumed that the evaluator does not influence the results, given the end point of the test is well defined (Verschuren et al., 2006; O. Verschuren, personal communication, September 29, 2011).

Timed-Up-And-Down-Stairs test. The TUDS evaluates the capacity to walk up and down a flight of stairs (Zaino et al., 2004). It is scored as the time(s) to
complete the task. Test results show convergent validity with the Timed Up and Go test for ambulatory children and youth with CP, $r_s = .68$ (Zaino et al., 2004). As stated in the introduction, TUDS scores show acceptable test-retest and interrater reliability (Zaino et al., 2004).

The pediatric (child) version of the Assessment of Life Habits (LIFE-HC). Community mobility was assessed using the mobility category of the short version of the LIFE-HC (Noreau et al., 2007). The Mobility category evaluates community mobility with items such as “moving around on streets and sidewalks.” The Life-HC mobility category scores for children and youth with CP show convergent validity with the mobility dimensions of the Pediatric Evaluation of Disability Inventory. The reported correlations are $r = .65$ to .68 (Noreau et al., 2007). Results from the Mobility category are also reliable for this group from day to day, with a test-retest ICC (2, 1) of .91 and an interevaluator ICC (2, 1) of .88 (two-way random, single measures model, with absolute agreement; Noreau et al., 2007; L. Noreau, personal communication, September 27, 2011). Scoring is on a 0–10 scale, which considers the level of difficulty in achieving a specific life habit (activity), the type of assistance required, and the number of items in the category.

Height and weight. Standing height was measured to the nearest 0.5 cm, with a stadiometer, using standardized and accepted methods (Docherty, 1996). Weight was measured to the nearest 0.1 kg on a recently calibrated scale. Participants were weighed in shorts and a t-shirt without shoes and after going to the washroom.

Procedure

With the exception of the LIFE-HC scores, all data were collected by two trained physical therapists during two visits to a local rehabilitation center. There were 2–14 days between visits. Participants arrived at the testing site for both visits well rested, having refrained from strenuous physical activity (sports, physical education class, outings) on the test day. Participants also refrained from eating for two hours and from consuming caffeine products for three hours before testing. Participants wore shorts, a t-shirt, and their typical sports shoes for the tests. Before data collection began, they rested (sitting) for an additional 15 min while the tests were explained to them.

During one visit, standing height and weight were measured. The 6MWT was performed on a 20-m walkway following standardized directions (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, 2002). Distance was indicated every 0.5 m. A visual target was placed at each end of the walkway to help the participant focus on the task as per Thompson et al. (2008).

During the other visit, the TUDS and the 10mSRT were performed; the later was always done at the end of the visit to avoid the possible influence of fatigue on the TUDS scores. For the TUDS, a 12-step staircase was used for all participants, with the exception of five. For these participants, an 11-step staircase was used because a 12-staircase was not available. When the 11-stair case was used, the time to ascend and descend a 12-step staircase was calculated by multiplying the time per step by 12, as there was no difference in riser height between the
Responses to the LIFE-HC items were recorded by a third evaluator (CF) via a face-to-face interview with a parent during one of the visits to the testing site. This evaluator was blind to the results from the locomotor capacity tests. The locomotor capacity test evaluators were also blind to the LIFE-HC results. Before the beginning of data collection, all evaluators received training in the relevant measurements and the precision of their measurements was verified.

**Statistical Analysis**

Participant characteristics, locomotor capacity test results, and community mobility scores (LIFE-HC mobility category scores) were summarized using descriptive statistics ($M$ and $SD$).

A hierarchical, stepwise regression analysis was performed to examine the ability of the 6MWT, the 10mSRT, and the TUDS to predict community mobility. With this method, the independent variables are introduced into the analysis singly or in blocks, in a predetermined order (Norman & Streiner, 2008). Control variables can be forced to remain in the model, but independent variables that are not significant predictors of the dependent variable are not maintained in the model (Norman & Streiner, 2008). This method was chosen because the effects of height and age on locomotor capacities could be controlled for in the analysis. The dependent variable was the LIFE-HC mobility category. The independent variables were the 6MWT, the 10mSRT, and the TUDS. The control variables were height and age. In step 1, these control variables were entered as a block. They were forced to remain in the model. The independent variables were entered as a second block in step 2. They were not forced to remain in the model. The standardized Beta coefficient ($\beta$) was used to evaluate how strongly each of the three locomotor test scores predicted community mobility. The coefficient of determination ($R^2$) and its $p$ value evaluated the fit of the model. A two-tailed significance level ($p$) of .05 was used for all tests. The statistical analyses were performed using SPSS, version 13.0 for Windows.

**Results**

Participant characteristics are summarized in Table 1. The results for the locomotor capacity tests and LIFE-HC mobility category are summarized in Table 2.

After age and height were controlled for in the regression analysis, the 10mSRT and the TUDS values explained about 40% of the variance in the LIFE-HC mobility category scores (Table 3). The 6MWT was not retained in the model because it was not a significant predictor of the mobility category scores ($\beta = .061, p = .720$). The 10mSRT variable had the highest $\beta$ value (.480, $p = .002$), indicating that of the three locomotor tests, it was the strongest predictor of the LIFE-HC mobility category scores. Better performance on the 10mSRT and on the TUDS was associated with better scores on the LIFE-HC mobility category (Table 3).
Discussion

This study evaluated the ability of three locomotor capacity tests, the 6MWT, the 10mSRT, and the TUDS, to predict community mobility in children and youth with CP who walk without support. After age and height were controlled for, the best predictors of community mobility were the tests of more advanced locomotor capacities, the 10mSRT and the TUDS. The 10mSRT was the strongest predictor.

Community Mobility

The children and youth in this study showed, on average, a somewhat mild restriction in community mobility, although individual scores did vary from 3.61 to 10. Not all the variance in the scores for community mobility, however, was accounted for by the results from the locomotor capacity tests. This is not surprising since factors unrelated to locomotor capacities, such as the physical and social environments of

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Locomotor Capacity and Community Mobility Test Scores</th>
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<tbody>
<tr>
<td>Variable</td>
<td>M (SD)</td>
</tr>
<tr>
<td>6MWT (m)</td>
<td>475.00 (81.70)</td>
</tr>
<tr>
<td>10mSRT (kph)</td>
<td>6.98 (1.20)</td>
</tr>
<tr>
<td>TUDS (s)</td>
<td>9.86 (4.26)</td>
</tr>
<tr>
<td>LIFE-HC Mobility category$^a$</td>
<td>8.04 (2.12)</td>
</tr>
</tbody>
</table>

*Note. N = 49. 6MWT = 6-min Walk Test; 10mSRT = 10-m Shuttle Run Test; TUDS = Timed-Up-and-Down-Stairs test; LIFE-HC = pediatric (child) version of the Assessment of Life Habits. $^a$The Mobility category scores are in arbitrary units. Values can vary from a minimum of 0 to a maximum of 10.*

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Hierarchical, Stepwise Regression Analysis Predicting Community Mobility From Locomotor Test Scores</th>
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<tbody>
<tr>
<td>Predictor</td>
<td>Community Mobility$^b$</td>
</tr>
<tr>
<td></td>
<td>$\Delta$ Adjusted R2</td>
</tr>
<tr>
<td>Step 1</td>
<td>.08</td>
</tr>
<tr>
<td>Control variable$^a$</td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td>.40</td>
</tr>
<tr>
<td>10mSRT</td>
<td>.48</td>
</tr>
<tr>
<td>TUDS</td>
<td>$-.34$</td>
</tr>
</tbody>
</table>

*Note. N = 49. 10mSRT = 10-meter Shuttle Run Test; TUDS = Timed-Up-and-Down-Stairs test; $\Delta$ Adjusted $R^2$ = change in the coefficient of determination corrected for the number of independent variables in the model; $\beta$ = Standardized Beta regression coefficient. $^a$Control variables were age and height. $^b$Community mobility was measured with the mobility category of the pediatric (child) version of the Assessment of Life Habits.*
the individual as well as his or her psychological makeup (Martin, 2006; Palisano et al., 2011; Spencer-Cavaliere & Watkinson, 2010), are also relevant to community mobility.

The Ten-Meter Shuttle Run Test and the Six-Minute Walk Test

While the 10mSRT was designed as a locomotor-based field test of aerobic capacity (Verschuren et al., 2006), it was strongly correlated in this present study, $r = .67$, $p < .001$, with the 6MWT distance, the gold standard clinical measure of level ground walking capacity (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, 2002). The 10mSRT, however, makes greater demands on the individual than does the 6MWT with respect to locomotion speed, direction change, control of acceleration and deceleration, and locomotor endurance (Verschuren et al., 2006). Thus, the 10mSRT may better reflect the level ground locomotor skills required for community mobility than the 6MWT or the 45-m walk test used by Lepage et al. (1998). Verschuren et al. (2007), for example, evaluated the effect on community mobility of training advanced locomotor capacities in children and youth with CP who walk without support. Following eight months of training, these participants, compared with the control group, showed higher scores on mobility-related activities as evaluated by the Children’s Assessment of Participation and Enjoyment and increased performance in advanced locomotor capacities as measured by the 10mSRT (Verschuren et al., 2007). The mean 10mSRT values in the current study (7.27 kph for GMFCS Level I and 5.25 kph for GMFCS level 2) were similar to those previously reported in the literature (7.0 kph for GMFCS Level I and 4.75 kph for GMFCS level 2; Verschuren et al., 2006). The mean value for the 6MWT (Table 2) was also similar to that in the literature for this population (486 m; Thompson et al., 2008).

Timed-Up-and-Down-Stairs Test

Aside from the work of Lepage et al. (1998), little has been published on the relationship between stair locomotor capacity and community mobility in children and youth with CP who walk without support. Even though these relationships have not been extensively evaluated in the literature, items measuring stair locomotion capacity are included in functional mobility assessments of children and youth with CP, such as the Gross Motor Function Measure (GMFM; Russell et al., 1989) and the mobility components of the Pediatric Evaluation of Disability Inventory (Haley, Coster, Ludlow, Haltiwanger, & Andrellos, 1992). Thus, the stair locomotor capacity of children and youth with CP is considered to be important to their mobility. The results of the current study, along with the findings of Lepage et al. (1998), provide evidence to support this assumption. Since both the 10mSRT and the TUDS were found to be independent predictors of community mobility in the present work, both tests may be used if one is interested in predicting the community mobility of children and youth with CP who walk without support. A comparison with TUDS values in the literature shows that, as expected, the participants in the current study were slower, mean TUDS = 0.82 s*step$^{-1}$, than similarly-aged typically developing youth, mean TUDS = 0.58 s*step$^{-1}$ (Zaino et al., 2004).
Limitations of the Study

The LIFE-HC mobility category scores showed a slight ceiling effect. Nine (18%) of the participants had the maximal score of 10. The participants who scored a 10 varied between 7.6 and 15.0 years old. The ceiling effect was therefore not restricted to the older participants. This supports the test creators’ recommendation that the test can be used with adolescents with a disability who are older than 13 years of age (Fougeyrollas, Noreau, & Lepage, 2001). Nevertheless, the ability of the locomotor capacity test scores to predict community mobility may have been underestimated due to this ceiling effect.

The effect of test order was only partially controlled. The 6MWT was performed during a different visit than the 10mSRT and the TUDS. Since the order of the visits was random, it is unlikely that the 6MWT systematically affected or was affected by learning from the other tests. The 10mSRT and the TUDS were performed on the same day. The 10mSRT was always performed after the TUDS. This was because the 10mSRT is a test to exhaustion and the time to recover from an exhaustive test is unknown for this group. Since the two tests require different skills (stair climbing vs. walking and running, turning quickly), it is unlikely that performing the TUDS influenced the 10mSRT scores. If there was an effect, however, it would have been in the same direction for all participants (improvement in 10mSRT scores due to learning as the result of performing the TUDS). Thus the pattern of the results would not have been affected.

While not a limitation per se, it should be noted that none of the results can be generalized to children and youth with CP who walk with support, as they were not evaluated in this study.

Recommendations for Future Research

It is important to control for the influence of growth and maturation on locomotor test results because they are personal factors not necessarily related to locomotor capacity limitations, but they can influence test results. Height and age were used as control variables in the current study. This choice was based on findings with children and youth with CP for the 10mSRT (Verschuren et al., 2010) and for the TUDS (Zaino et al., 2004) and based on findings for typically developing children and youth for the 6MWT (Geiger et al., 2007). Since data on the best growth- and maturation-related variables to predict 6MWT results for children and youth with CP have not been published, further research with this population is required to confirm that the Geiger et al. (2007) results also hold true for the population with CP.

An interview was used in the current study to evaluate community mobility so that the results could be compared with the previous work of Lepage et al. (1998). Parents were interviewed because children under eight years old may have difficulties responding accurately to the types of questions that are used to evaluate community mobility (Young, Yoshida, Williams, Bombardier, & Wright, 1995). Future work should combine interview information with objective measures of community mobility such as accelerometry (Clanchy, Tweedy, Boyd, & Trost, 2011) and global positioning systems technology (Maddison et al., 2010). When used together, these objective measures could provide additional information on the intensity of community mobility activities, their pattern, and where in the community the activities
take place. These types of data could be used to better understand the impact on community mobility of changes in locomotor test scores following interventions.

**Conclusion**

Results from tests of advanced locomotor capacities appear to be better predictors of community mobility in children and youth with CP who walk without support than results from a level ground walking test. To better understand how the community mobility of this group is affected by changes in their locomotor capacity test scores, further work is required to characterize the intensity, pattern, and specific environment of their community mobility.

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**References**


