

Physical Therapy

Journal of the American Physical Therapy Association and



de Fysiotherapeut

Royal Dutch Society for Physical Therapy



Reproducibility and Validity of the 10-Meter Shuttle Ride Test in Wheelchair-Using Children and Adolescents With Cerebral Palsy

Olaf Verschuren, Maremka Zwinkels, Marjolijn Ketelaar, Femke Reijnders-van Son and Tim Takken

PHYS THER. Published online April 11, 2013

Originally published online April 11, 2013

doi: 10.2522/ptj.20120513

The online version of this article, along with updated information and services, can be found online at: <http://ptjournal.apta.org/content/early/2013/05/15/ptj.20120513>

Collections

This article, along with others on similar topics, appears in the following collection(s):

[Cardiovascular/Pulmonary System: Other](#)
[Cerebral Palsy](#)
[Cerebral Palsy \(Pediatrics\)](#)
[Tests and Measurements](#)

E-mail alerts

Sign up [here](#) to receive free e-mail alerts

Online First articles are published online before they appear in a regular issue of *Physical Therapy* (PTJ). PTJ publishes 2 types of Online First articles:

Author manuscripts: PDF versions of manuscripts that have been peer-reviewed and accepted for publication but have not yet been copyedited or typeset. This allows PTJ readers almost immediate access to accepted papers.

Page proofs: edited and typeset versions of articles that incorporate any author corrections and replace the original author manuscript.

Reproducibility and Validity of the 10-Meter Shuttle Ride Test in Wheelchair-Using Children and Adolescents With Cerebral Palsy

Olaf Verschuren, Maremka Zwinkels, Marjolijn Ketelaar, Femke Reijnders-van Son, Tim Takken

Background. For children with cerebral palsy (CP) who are able to walk or run, the 10-m shuttle run test is currently the test of choice to assess cardiorespiratory fitness. This test, however, has not yet been examined in wheelchair-using youth with CP.

Objective. The purpose of this study was to investigate the test-retest reproducibility and validity of the 10-m shuttle ride test (SRiT) in youth with CP.

Design. Repeated measurements of the SRiT were obtained.

Methods. Twenty-three individuals with spastic CP (18 boys, 5 girls; mean age = 13.3 years, SD = 3.6 years) using a manual wheelchair for at least part of the day participated in this study. During the study, all participants performed one graded arm exercise test (GAET) and 2 identical SRiTs within 2 weeks. Peak oxygen uptake ($\dot{V}O_{2peak}$), peak heart rate (HR_{peak}), and respiratory exchange ratio (RER) were recorded. Intraclass correlation coefficients (2,1), the smallest detectable difference, and the limits of agreement (LOA) were calculated. The association between the results of the SRiT and GAET was tested using Pearson correlation coefficients.

Results. Intraclass correlation coefficients (.99, 95% confidence interval = .98–1.00) for all variables indicated highly acceptable reproducibility. The LOA analysis revealed satisfactory levels of agreement. The SRiT variables demonstrated strong, significant positive correlations for $\dot{V}O_{2peak}$ values obtained during the SRiT and the GAET ($r = .84$, $P < .01$).

Limitations. Although the GAET is considered the gold standard, the cardiorespiratory demand during the GAET was significantly lower compared with during the SRiT. Future studies should determine whether the GAET can still be accepted as the gold standard for upper-extremity exercise.

Conclusions. The SRiT is a reproducible and valid test for measuring cardiorespiratory fitness in youth with spastic CP who self-propel a manual wheelchair.

O. Verschuren, PT, PhD, Rudolf Magnus Institute of Neuroscience and Center of Excellence for Rehabilitation Medicine, University Medical Center Utrecht and De Hoogstraat Rehabilitation, Utrecht, the Netherlands. Mailing address: Rehabilitation Centre De Hoogstraat, Rembrandtkade 10, 3583 TM Utrecht, the Netherlands. Address all correspondence to Dr Verschuren at: o.verschuren@dehoogstraat.nl.

M. Zwinkels, MSc, Rudolf Magnus Institute of Neuroscience and Center of Excellence for Rehabilitation Medicine, University Medical Center Utrecht and De Hoogstraat Rehabilitation.

M. Ketelaar, PhD, Rudolf Magnus Institute of Neuroscience and Center of Excellence for Rehabilitation Medicine, University Medical Center Utrecht and De Hoogstraat Rehabilitation.

F. Reijnders-van Son, PT, MSc, Child Expertise Centre, Tolbrug Specialistic Rehabilitation, 's-Hertogenbosch, the Netherlands.

T. Takken, PhD, Child Development and Exercise Center, Wilhelmina Children's Hospital, University Medical Center Utrecht.

[Verschuren O, Zwinkels M, Ketelaar M, et al. Reproducibility and validity of the 10-meter shuttle ride test in wheelchair-using children and adolescents with cerebral palsy. *Phys Ther*. 2013;93:xxx-xxx.]

© 2013 American Physical Therapy Association

Published Ahead of Print:

April 11, 2013

Accepted: April 4, 2013

Submitted: December 17, 2012



Post a Rapid Response to this article at:
ptjournal.apta.org

Autonomous mobility, or getting from place to place without relying on other people, is desirable for social and community participation for wheelchair-using youth. A relationship between mobility and participation has been documented for children and youth with cerebral palsy (CP).^{1,2} Children with more severe types of CP (ie, Gross Motor Function Classification System [GMFCS] levels III and IV) have to rely, for short or longer distances, on a manually propelled wheelchair for mobility. Children and youth who do not walk are more likely to have limited participation.² Thus, improving wheelchair mobility is an important goal for this group of children. Wheelchair mobility is not always optimal. This situation could be due to: (1) the vehicle mechanics of the wheelchair, (2) the wheelchair design is not appropriate for the user, or (3) the individual's functional capacity.³ If the individual's functional capacity is the limiting factor in wheelchair mobility, the assessment of cardiorespiratory fitness of wheelchair users might be an important area of interest in physical rehabilitation, especially as a low cardiorespiratory fitness level is associated with shorter life expectancy and a higher risk of developing type II diabetes, cardiovascular disease, and some types of cancer.^{4,5}

Exercise testing over time can provide a quantitative assessment of the improvement or decline in the cardiorespiratory fitness (aerobic capacity) of children and adolescents with CP and has the potential to be an important measurement tool in clinical practice as well as in research.⁶ Exercise testing, with direct measurements of maximal oxygen uptake ($\dot{V}O_2$), provides the most widely recognized and accurate index of cardiorespiratory fitness. However, there are limited outcome tools to assess cardiorespiratory fitness easily and accurately in individ-

uals with CP who rely on a manually propelled wheelchair for short or longer distances. A common approach for wheelchair users has been laboratory tests evaluating maximal cardiorespiratory adaptations during arm cranking.⁷⁻⁹ However, such tests require many resources in terms of qualified personnel and sophisticated instrumentation, which are not always available.

Field tests can serve as an alternative when the cardiorespiratory fitness of wheelchair users needs to be evaluated. For children with CP who are able to walk or run independently, running-based field tests, such as the 10-m shuttle run tests (SRT-I, SRT II, and SRT-III), are currently used in clinical practice to assess cardiorespiratory fitness and are inexpensive measures that do not require special equipment or training.^{10,11} Moreover, the 10-m distance makes these tests appropriate for most clinicians because only a small gym or hallway is required. These 10-m test protocols, however, have not yet been examined in wheelchair-using youth with CP. Reproducibility and validity of field exercise tests are important issues for clinical outcomes. Therefore, the objective of this study was to investigate the test-retest reproducibility and validity of the 10-m shuttle ride test (SRiT) in wheelchair-using youth with CP.

Method

Participants

This study focused on children and adolescents with CP between the ages of 7 and 18 years who were diagnosed with spastic CP and classified at Gross Motor Function Classification System Expanded and Revised¹² (GMFCS-E&R) levels III and IV. All participants were required to self-propel a manual wheelchair for at least a part of the day and were capable of following simple instructions.

Table 1.

Participant Characteristics (N=23)^a

Variable	Values
Age (y)	13.3±3.6
Height (cm)	149.6±14.3
Height for age SDS	-1.48±1.07
Body mass (kg)	42.3±13.1
Body mass for age SDS	1.05±1.03
BMI (kg/m ²)	18.5±4.0
BMI for age SDS	-0.47±1.96
GMFCS, n	
Level III	3
Level IV	20

^a Age, body height, body mass, body mass index (BMI), and standard deviation score (SDS)¹¹ data are reported as \bar{X} ±SD. GMFCS=Gross Motor Function Classification System.

Four schools for special education were informed about the study and the inclusion and exclusion criteria. Based on clinical examination, pediatric physiatrists working in these schools referred suitable participants. A total of 23 children with CP (18 boys, 5 girls; mean age=13.3 years, SD=3.6) and their parents provided informed consent for participation in this study. All children received rehabilitation services in the Netherlands at the time of participation. Participant characteristics are provided in Table 1.

Procedure

All participants attended a total of 3 testing sessions. Participants were blinded to their performance on each of the tests. All tests were performed within a period of 2 weeks in 4 rehabilitation centers across the Netherlands and were supervised by 2 experienced assessors.

Prior to testing, each participant's body mass was determined using an electronic scale, (Stimag, Hoofddorp, the Netherlands), and height was assessed in a supine position. The weight of the participant's wheelchair also was determined using an electronic scale. Functional

mobility was quantified using the Functional Mobility Scale (FMS).¹³

To assess test-retest reliability of the SRiT, each participant performed the SRiT twice. To assess validity, we compared the peak oxygen uptake ($\dot{V}O_{2peak}$) achieved during the graded arm exercise test (GAET) with $\dot{V}O_{2peak}$ during the SRiT. The GAET and the SRiT were separated by a minimum of 2 days and a maximum of 7 days ($\bar{X}=4.1$, $SD=1.4$).

Measures

GMFCS. A pediatric physical therapist experienced in using the GMFCS-E&R^{12,14} utilized the translated Dutch version to classify the children and adolescents with CP according to their functional ability.

FMS. The FMS, a reliable and valid instrument, is a 6-point ordinal scale that quantifies mobility according to the need for assistive devices at 3 specific distances: 5, 50, and 500 m.^{13,15} These distances represent home, school, and community environments, respectively. The FMS is administered by asking the child or parent a few questions and to indicate whether the child uses a wheelchair (score=1) or is ambulatory with or without assistive devices (score=2-6) for every distance.

GAET. The GAET was performed using a protocol that we developed during pilot testing. The child used his or her arms for cranking while sitting on a chair. The axle of the pedals was adjusted at shoulder height such that the elbow joint was almost in full extension (165° - 175°) when the participant's hands were grasping the handles (synchronously) with the crank horizontally positioned away from the body. The child was seated comfortably, supported by the back of the seat or by a pillow and was asked to remain seated throughout the test. Strapping in was needed to stabilize some

participants to minimize leg motion. The test was performed on an electromagnetically braked cycle ergometer (Lode Angio, Procure BV, Groningen, the Netherlands). The ergometer was fixed to the floor to prevent any ergometer movement during the test.

The protocol consisted of 3 parts: (1) warm-up: the participant had to crank at a comfortable pace for 1 minute; (2) load-phase: every minute the load increased by 8 W, starting at 0 W, and all participants were verbally encouraged to maintain their cadence (revolutions per minute [rpm]) within 40 to 60 rpm throughout the test; and (3) recovery: once the test was completed, participants were given a chance to crank at their own pace for as long as they desired without a braking force.

SRiT. The shuttle run test protocol that was originally developed for children with a GMFCS level II classification was used.¹⁰ The starting speed, as indicated by the beeps on the test CD, is 2 km/h, and the increase in speed is 0.25 km/h every minute. The SRiT requires children to propel the wheelchair between 2 markers delineating the respective course of 10 m, at a set incremental speed determined by a signal, which is played by a standard CD player. All participants were accompanied by a physical therapist during the test to help them pace themselves with the audio signal. At the end of each level, the participants were told to go a little faster. The test was finished when, on 2 consecutive paced signals, the participants were more than 1.5 m away from the marker. Total exercise time and heart rate at the end of the test were recorded and used for analysis. All children used their own wheelchair during the tests.

Before the GAET and SRiT, the participants were given adequate expla-

nation of the proposed protocol and its objectives. They were encouraged to push themselves to their limits, and the test was stopped when they were unable or refused to continue the test despite encouragement. The subjective criteria of intense effort, such as an unsteady arm crank (<30 rpm) or propelling pattern, sweating, facial flushing, or a clear unwillingness to continue exercising despite repeated strong verbal encouragement, were used to determine whether the test was maximal. Each child had to meet at least 2 subjective criteria at the end of the tests. All tests were performed under standardized conditions in a laboratory environment. The participants maintained their normal diet before the day of testing. Only light physical activity was performed on the day before testing, and on the test day, participants did not exercise before their test visit.

Study Design

During the study, all participants performed 2 identical SRiTs and one GAET within 2 weeks to assess the reliability and validity of the measurements. One SRiT and one GAET were performed while wearing a facemask and a mobile gas analysis system (Cortex Metamax, Cortex-Medical GmbH, Leipzig, Germany). The participants also completed one SRiT without mobile gas analysis system. The testing was done while the participants were wearing regular clothing.

During the GAET and SRiT with gas analysis, the participants wore a firmly fitted facemask attached to a calibrated mobile gas analysis system with an in-built gas analyzer, which allowed gas analysis throughout the test. Measurements of cardiopulmonary variables were collected. Before each trial started, the participants rested until they had a stable heart rate. Their heart rate was measured continuously, and the measurements

Shuttle Ride Test in Wheelchair-Using Youth With CP

Table 2.

Results of the 10-m Shuttle Ride Test (SRiT) and Graded Arm Exercise Test (GAET) (N=23)

Measure	\bar{X}	SD	Range
SRiT			
Exercise time (min)	8.0	4.9	1–16
HRpeak ^a (bpm)	171.0	23.2	122–206
GAET			
Exercise time (min)	5.6	3.0	0.5–14.0
HRpeak (bpm)	160.5	24.5	117–194

^aHRpeak=peak heart rate.

were saved to a storage device during all tests using a reliable and accurate heart rate monitor.¹⁶ The Cortex Metamax is a valid and reliable system for measuring ventilatory parameters during exercise.^{17–19}

The mobile gas analysis system consisted of a facemask, a transmitting unit (containing different oxygen and carbon dioxide gas analyzers), and a receiving unit. The transmitting unit with facemask and tubing (total weight=0.57 kg) was attached to the child with a harness, and the receiving unit was connected to a laptop computer located within 500 m of the transmitting unit. Metabolic stress test software (Metasoft, version 2.6, Cortex-Medical GmbH, Leipzig, Germany) was used to measure minute ventilation, \dot{V}_{O_2} , carbon dioxide production (\dot{V}_{CO_2}), and heart rate and to calculate the respiratory exchange ratio ($RER = \dot{V}_{CO_2} / \dot{V}_{O_2}$) every 10 seconds.

During the SRiT without gas analysis, only the participants' heart rate was monitored. The heart rate was read from the wrist monitor at the end of the test and recorded on the datasheet.

Data Analysis

Reproducibility. Reproducibility encompasses both reliability and agreement.²⁰ To assess reliability, intraclass correlation coefficients

(ICC [2,1]) were used. An ICC > .80 reflects excellent reliability, and ICCs from .70 to .79 reflect good reliability.²¹ The recommended minimum for the lower bound of the 95% confidence interval (95% CI) is .85.²² For agreement, the standard error of measurement (SEM) was used to determine the precision of the total score of both tests. The SEM describes the error in interpreting the test score of an individual. It allows for estimation of the "true" test performance using a reliability coefficient and is computed as the standard deviation of the total score multiplied by the square root of 1 minus its reliability coefficient ($SEM = SD \times \sqrt{1 - ICC}$). It is important to know, especially in clinical practice, whether the test-retest differences on an individual basis are exceeding a smallest detectable difference (SDD) of 1. The SDD of the total score was computed as $1.96 \times \sqrt{2} \times SEM$ to obtain a 95% CI value.²⁰

To determine whether there were significant differences for peak heart rate (HRpeak), \dot{V}_{O_2} peak, peak ventilation (\dot{V}_{E} peak), and RER between the GAET and the SRiT, the data were compared using paired *t* tests. The Bland-Altman procedure was used to check for heteroscedasticity of the test and retest of the SRiT.²³ Furthermore, the consistency of measurements was verified graphi-

cally using the method of Bland and Altman.²³ This method plots differences between 2 measurements against the average of the 2 measurements. Size and range of differences, scoring distribution, and possible measurement bias can be visually assessed. The Bland and Altman limits of agreement (LOA)²³ were used to evaluate the level of agreement between test and retest. The LOA define the limits within which 95% of the differences are expected to fall ($mean \pm 1.96$ SD of the differences).

Validity. The association between the results of the SRiT and GAET was tested using the Pearson correlation coefficients (*r*). An alpha level of <.05 was considered statistically significant.²¹ Finally, a *post hoc* power calculation was conducted to assess whether the study had adequate sample size.

Role of the Funding Source

The study was funded by the Dr W.M. Phelps Foundation. The funder had no role in the design, the data collection, analysis, and interpretation; the reporting of this work, or the decision to submit the work for publication.

Results

All of the participants completed all tests without complications. Twenty-one children were bimanually functional, and 2 children used one arm to propel and one arm to steer their wheelchair using a steering wheel. The FMS data show that 11, 14, and 23 children used their wheelchair at home, at school, and in community environments, respectively. Eight children did not wear a facemask because the thought of breathing through the mouthpiece frightened them, and only heart rate was monitored during the exercise tests.

The following results refer to both sexes and GMFCS levels. The physiological variables measured on both exercise tests are provided in Table 2.

Reproducibility

The test-retest reliability statistics of the SRiT are presented in Table 3. The ICC value for exercise time was .99, with an SEM of 0.5 and an SDD of 1.4. The ICC value for HRpeak was .99, with an SEM of 2.3 and an SDD of 6.4. As can be appreciated from the Bland-Altman plots (Figs. 1 and 2), there were some obvious outliers. These outliers were included in the calculations. The 2 children who propelled their wheelchair with one arm had the lowest performance on the SRiT.

Validity

In 8 participants, the $\dot{V}O_{2peak}$, RER, and $\dot{V}E_{peak}$ were not monitored. These participants' data, therefore, were not included in the validity analysis. The physiological variables measured on both tests in which $\dot{V}O_{2peak}$ values were obtained are presented in Table 4. There was a strong and significant correlation between the $\dot{V}O_{2peak}$ and HRpeak values obtained during the SRiT and the GAET ($r = .84$, $P < .01$ and $r = .80$, $P < .01$, respectively). There was a significant but weak correlation between the RER values obtained during the SRiT and the GAET ($r = .63$, $P < .01$).

Post Hoc Power Calculation

The calculation of the statistical power for validity was performed *post hoc* using the sample size of 15, the correlation coefficient of .84, and a P value of .05. The results indicated that this study had a power of >0.9 to detect a significant correlation between the 2 tests.

Discussion

The purpose of this study was to determine the 2 aspects of reproducibility (reliability and agreement) and

Table 3.
Test-Retest Reliability Statistics^a

SRIT	ICC	95% CI of ICC	SEM	SDD	LOA
Exercise time (min)	.99	.98–1.00	0.5	1.4	–1.45 to 1.45
HRpeak (bpm)	.99	.98–1.00	2.3	6.4	–9.9 to 8.1

^a SRiT=10-m shuttle ride test, HRpeak=peak heart rate, ICC=intraclass correlation coefficient, 95% CI=95% confidence interval, SEM=standard error of measurement, SDD=smallest detectable difference, LOA=limits of agreement.

validity of the SRiT in children and adolescents with CP who self-propel a manual wheelchair. Reliability of the SRiT can be considered excellent, with ICCs of .99 (95% CI=.98–1.00). Agreement was good, as

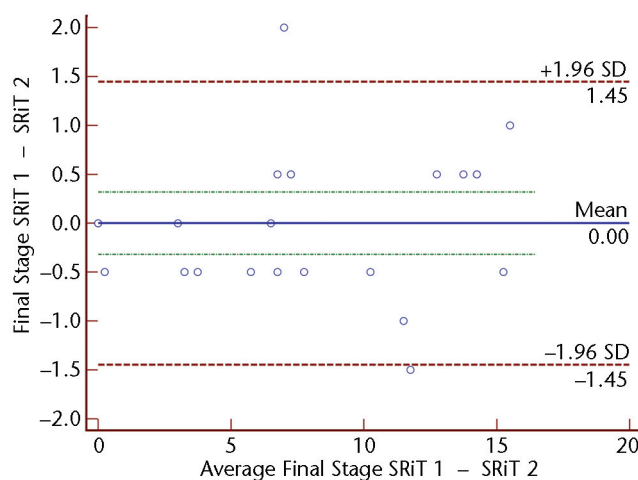


Figure 1.
Bland-Altman plot of test and retest on the final stage of the 10-m shuttle ride test (SRiT).

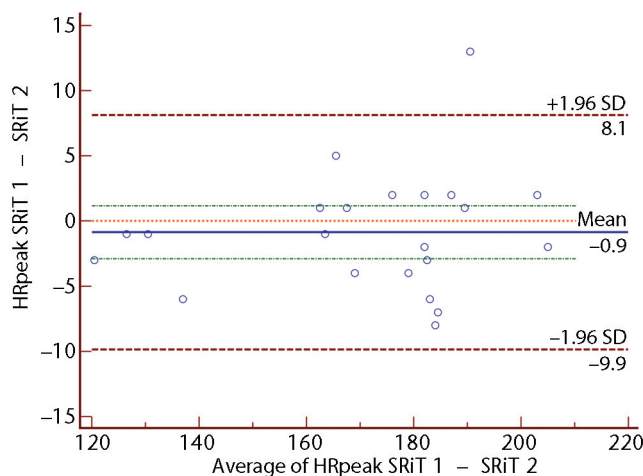


Figure 2.
Bland-Altman plot of test and retest of peak heart rate (HRpeak) during the 10-m shuttle ride test (SRiT).

Shuttle Ride Test in Wheelchair-Using Youth With CP

Table 4.

Validity Statistics (n=15)^a

Variance	SRiT		GAET		Difference
	\bar{X}	SD	\bar{X}	SD	
$\dot{V}O_{2peak}$ (mL/kg/min)	26.0	5.0	25.3	5.7	0.7
RER _{peak}	1.1	0.2	1.0	0.1	0.1
$\dot{V}E_{peak}$ (L/min)	46.4	20.8	36.9	15.1	6.5 ^b
HR _{peak} (bpm)	171.8	23.0	160.5	24.5	11.3 ^b
O ₂ pulse (mL/beat)	6.37	2.26	6.4	2.11	0.02
$\dot{V}E_{peak}/\dot{V}O_{2peak}$	43.43	12.86	35.61	9.51	7.8 ^b
$\dot{V}E_{peak}/\dot{V}CO_{2peak}$	39.46	9.86	34.57	8.13	4.9 ^b

^a SRiT=10-m shuttle ride test, GAET=graded arm exercise test, $\dot{V}O_{2peak}$ =peak oxygen uptake, RER=respiratory exchange ratio, $\dot{V}E_{peak}$ =peak minute ventilation, $\dot{V}CO_{2peak}$ =peak carbon dioxide production, HR_{peak}=peak heart rate, O₂ pulse=oxygen pulse ($\dot{V}O_{2peak}/HR_{peak}$).

^b $P<.05$ for the comparison of the SRiT and the GAET.

reflected by the narrow LOA. The ICCs for the SRiT are similar with those previously reported for SRT in the literature, ranging from .97 to .99 for children with CP classified at GMFCS level I, II, or III.^{10,11} Moreover, significant correlations between the $\dot{V}O_{2peak}$ values on the SRiT and the GAET were found, indicating that the SRiT is a valid test for the assessment of cardiorespiratory fitness in children with CP who self-propel a wheelchair.

The SRiT is inexpensive and easy to administer. This test does not require any special equipment or extensive training, making it almost directly available for a variety of exercise professionals working with children and adolescents with CP. During the tests, each participant's heart rate was measured continuously, and all participants were instructed to exercise until exhaustion. For children and adolescents who are able to walk independently, the physiological objective criterion of a heart rate >180 or >185 bpm is frequently used to determine whether the test is performed maximally.²⁴ However, for people who are self-propelling a wheelchair or are arm cranking during an exercise test, this criterion might not be appropriate because peak heart rate

is significantly lower during arm exercise compared with leg exercise.²⁵ This difference might be explained by a lower recruited muscle mass or an insufficient muscle strength or skill. Moreover, it also has been thought that a limitation of arm crank ergometer tests is that maximal exhaustion of the cardiorespiratory system is not achieved because the upper extremities may experience muscle fatigue before the "maximal" aerobic capacity is reached.⁸

Based on the results from a series of field tests for adults who use a wheelchair for sport purposes, Vanlandewijck et al²⁶ suggested that their shuttle test was related to not only to $\dot{V}O_{2peak}$ but also to anaerobic performance. According to these authors, the 180-degree turn after each 25 m and the resulting cumulative decelerations and accelerations of the wheelchair-user system probably solicited anaerobic energy sources to some extent. For the SRiT used in the present study, the same factors might apply. Moreover, impaired wheelchair skills, which make it more difficult to make the 180-degree turn every 10 m, might have influenced the results of the SRiT. However, when comparing the

SRiT results with the GAET results, the $\dot{V}O_{2peak}$ values are comparable.

The $\dot{V}E_{peak}$ was significantly higher during the SRiT than during the GAET. Also, $\dot{V}E_{peak}/\dot{V}O_{2peak}$ and $\dot{V}E_{peak}/\dot{V}CO_{2peak}$ were significantly higher during the SRiT than during the GAET. In the study by Verschuren and Takken,²⁷ the $\dot{V}E_{peak}$ values of children with CP, classified at GMFCS level I or II, were 58.1 L/min (SD=21.7). These values are higher than the $\dot{V}E_{peak}$ values found in this study for the SRiT and GAET, which were 47.4 L/min (SD=21.0) and 36.9 L/min (SD=15.1), respectively. The lower $\dot{V}E_{peak}$ values in the current study can be explained by the fact that the lower $\dot{V}O_{2peak}$ (and $\dot{V}CO_{2peak}$) values observed during arm exercise also will result in lower $\dot{V}E_{peak}$ values because $\dot{V}CO_2$ is the major determinant for ventilator drive.²⁸ It is of interest to note that the $\dot{V}E_{peak}/\dot{V}O_{2peak}$ during the SRiT (43.4) was significantly higher than previously observed during running in youth with CP (35.4, $P=.01$).²⁷ This finding indicates that the ventilator efficiency is lower during riding than during running.

During the SRiT, not all children reached an HR_{peak} of 180 bpm (range=122–206) or higher at the end of the test. This finding indicates that, according to the physiological criteria established by Schulze-Neick et al,²⁴ these children did not reach a near-maximal effort during the test. Thus, for some children, the SRiT does not stress the cardiorespiratory system. However, all children did meet the subjective criteria because they all had signs of intense effort such as sweating, facial flushing, and a clear unwillingness to continue propelling their wheelchair despite repeated strong verbal encouragement. This finding suggests that for some children the cardiorespiratory system was not the limiting factor. This finding might be explained

by the fact that the skill required when propelling a wheelchair can be difficult for some children with CP. Aspects related to spasticity, co-contraction, and poor motor control may reflect mechanical inefficiency, which results in a low performance on the SRiT.

Several limitations affected the present study. One limitation of this study was the use of the GAET. Although the GAET is considered the gold standard for upper-extremity ergometry, the cardiorespiratory demand (HR_{peak} , $\dot{V}E_{peak}$) during this test was significantly lower compared to the SRiT. Future studies should determine whether arm ergometry can still be accepted as the gold standard for upper-extremity ergometry. Other possibilities for the GAET are wheelchair based-tests on the treadmill or wheelchair ergometer.^{29,30}

A second limitation was the small sample used to examine validity of the SRiT. The $\dot{V}O_{2peak}$ data of only 15 individuals were used for the analysis. However, as the *post hoc* sample size calculation indicated, this study was sufficiently powered.

Moreover, a general limitation of validation studies is that the results are not necessarily transferable to another population. The sample size in the present study also was inadequate to compare the reproducibility and validity of subsets for age, sex, or GMFCS level. In future studies, the sample size needs to be increased for further assessment of reproducibility and validation of the SRiT.

A fourth limitation is the fact that the influence of the wheelchair design was not examined. It would be interesting to investigate in future research whether differences in wheelchair design may have an impact on the ability of the participant to perform the required task.

In conclusion, the SRiT is a reproducible and valid test for measuring cardiorespiratory fitness in youth with CP. The SRiT is easy to administer and inexpensive. Clinicians using this test do not need special equipment or training, which makes this test available for a variety of professionals working with children and adolescents with CP.

Dr Verschuren, Dr Ketelaar, and Dr Takken provided concept/idea/research design and fund procurement. All authors provided writing. Dr Verschuren, Ms Zwinkels, Ms Reijnders-van Son, and Dr Takken provided data collection. Dr Verschuren and Dr Takken provided data analysis and project management. Ms Reijnders-van Son and Dr Takken provided facilities/equipment. Dr Ketelaar provided consultation (including review of manuscript before submission). The authors are grateful to the children, their parents, and the physical therapists from Ariane de Ranitz, Rehabilitation Centre Blixembosch, Mytyschool Eindhoven, Tolbrug Specialistic Rehabilitation, Mytyschool Gabriël, and Emiliusschool who volunteered their time and assistance.

The Institutional Review Board of the University Medical Center Utrecht, approved the study.

The study was funded by the Dr W.M. Phelps Foundation.

DOI: 10.2522/ptj.20120513

References

- 1 Lepage C, Noreau L, Bernard PM. Association between characteristics of locomotion and accomplishment of life habits in children with cerebral palsy. *Phys Ther*. 1998;78:458-469.
- 2 Palisano RJ, Kang LJ, Chiarello LA, et al. Social and community participation of children and youth with cerebral palsy is associated with age and gross motor function classification. *Phys Ther*. 2009;89:1304-1314.
- 3 van der Woude LH, Veeger DJ, Rozendal RH. Ergonomics of wheelchair design: a prerequisite for optimum wheeling conditions. *Adv Phys Act Q*. 1989;6:109-132.
- 4 Blair SN, Kampert JB, Kohl HW III, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA*. 1996;276:205-210.
- 5 Myers J, Prakash M, Froelicher VF, et al. Exercise capacity and mortality among men referred for exercise testing. *N Engl J Med*. 2002;346:793-801.

- 6 Unnithan VB, Clifford C, Bar-Or O. Evaluation by exercise testing of the child with cerebral palsy. *Sports Med*. 1998;26:239-251.
- 7 van den Berg-Emons RJ, van Baak MA, de Barbanson DC, et al. Reliability of tests to determine peak aerobic power, anaerobic power and isokinetic muscle strength in children with cerebral palsy. *Dev Med Child Neurol*. 1996;38:1117-1125.
- 8 Bar-Or O, Zwiren LD. Maximal oxygen consumption test during arm exercise: reliability and validity. *J Appl Physiol*. 1975;38:424-426.
- 9 Maltas D, Kondo I, Bar-Or O. Arm cranking economy in spastic cerebral palsy: effects of different speed and force combinations yielding the same mechanical power. *Pediatr Exerc Sci*. 2000;12:258-269.
- 10 Verschuren O, Takken T, Ketelaar M, et al. Reliability and validity of data for 2 newly developed shuttle run tests in children with cerebral palsy. *Phys Ther*. 2006;86:1107-1117.
- 11 Verschuren O, Bosma L, Takken T. Reliability of a shuttle run test for children with cerebral palsy who are classified at Gross Motor Function Classification System level III. *Dev Med Child Neurol*. 2011;53:470-472.
- 12 Palisano RJ, Rosenbaum P, Bartlett D, Livingston MH. Content validity of the expanded and revised Gross Motor Function Classification System. *Dev Med Child Neurol*. 2008;50:744-750.
- 13 Graham HK, Harvey A, Rodda J, et al. The Functional Mobility Scale (FMS). *J Pediatr Orthop*. 2004;24:514-520.
- 14 Palisano RJ, Rosenbaum P, Walter S. The development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol*. 1997;39:214-223.
- 15 Harvey AR, Morris ME, Graham HK, et al. Reliability of the functional mobility scale for children with cerebral palsy. *Phys Occup Ther Pediatr*. 2010;30:139-149.
- 16 MacFarlane DJ, Fogarty BA, Hopkins WC. The accuracy and variability of commercially available heart rate monitors. *New Zealand Journal of Sports Medicine*. 1989;17:51-53.
- 17 Medbo JL, Mamen A, Welde B, et al. Examination of the Metamax I and II oxygen analysers during exercise studies in the laboratory. *Scand J Clin Lab Invest*. 2002;62:585-598.
- 18 Meyer T, Georg T, Becker C, Kindermann W. Reliability of gas exchange measurements from two different spirometry systems. *Int J Sports Med*. 2001;22:593-597.
- 19 Brehm MA, Harlaar J, Groepenhof H. Validation of the portable VmaxST system for oxygen-uptake measurement. *Gait Posture*. 2004;20:67-73.
- 20 de Vet HC, Terwee CB, Knol DL, Bouter LM. When to use agreement versus reliability measures. *J Clin Epidemiol*. 2006;59:1033-1039.

Shuttle Ride Test in Wheelchair-Using Youth With CP

- 21 Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. East Norwalk, CT: Appleton & Lange; 2000.
- 22 Streiner DL, Norman GR. *Health Measurement Scales. A Practical Guide to Their Development and Use*. 2nd ed. Oxford, United Kingdom: Oxford University Press; 2000.
- 23 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*. 1986;1:307-310.
- 24 Schulze-Neick IM, Wessel HU, Paul MH. Heart rate and oxygen uptake response to exercise in children with low peak exercise heart rate. *Eur J Pediatr*. 1992;151:160-166.
- 25 Schrieks IC, Barnes MJ, Hodges LD. Comparison study of treadmill versus arm ergometry. *Clin Physiol Funct Imaging*. 2011;31:326-331.
- 26 Vanlandewijck Y, van de Vliet P, Verellen J, Theisen D. Determinants of shuttle run performance in the prediction of peak $\dot{V}O_2$ in wheelchair users. *Disabil Rehabil*. 2006;28:1259-1266.
- 27 Verschuren O, Takken T. Aerobic capacity in children and adolescents with cerebral palsy. *Res Dev Disabil*. 2010;31:1352-1357.
- 28 Giardini A, Odendaal D, Khambadkone S, Derrick G. Physiologic decrease of ventilatory response to exercise in the second decade of life in healthy children. *Am Heart J*. 2011;161:1214-1219.
- 29 Haisma JA, van der Woude LH, Stam HJ, et al. Physical capacity in wheelchair-dependent persons with a spinal cord injury: a critical review of the literature. *Spinal Cord*. 2006;44:642-652.
- 30 Franklin BA. Exercise testing, training and arm ergometry. *Sports Med*. 1985;2:100-119.

Physical Therapy

Journal of the American Physical Therapy Association and



Reproducibility and Validity of the 10-Meter Shuttle Ride Test in Wheelchair-Using Children and Adolescents With Cerebral Palsy

Olaf Verschuren, Maremka Zwinkels, Marjolijn Ketelaar, Femke Reijnders-van Son and Tim Takken
PHYS THER. Published online April 11, 2013
Originally published online April 11, 2013
doi: 10.2522/ptj.20120513

**Subscription
Information**

<http://ptjournal.apta.org/subscriptions/>

Permissions and Reprints

<http://ptjournal.apta.org/site/misc/terms.xhtml>

Information for Authors

<http://ptjournal.apta.org/site/misc/ifora.xhtml>
