Original Research

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6-Minute Push Test in Youth Who Have Spina Bifida and Who Self-Propel a Wheelchair: Reliability and Physiologic Response

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Objective. Despite the common occurrence of lower levels of physical activity and physical fitness in youth with spina bifida (SB) who use a wheelchair, there are very few tests available to measure and assess these levels. The purpose of this study was to determine reliability and the physiologic response of the 6-minute push test (6MPT) in youth with SB who self-propel a wheelchair.

Methods. In this reliability and observational study, a sample of 53 youth with SB (5–19 years old; mean age = 13 years 7 months; 32 boys and 21 girls) who used a wheelchair performed 2 exercise tests: the 6MPT and shuttle ride test. Heart rate, minute ventilation, respiratory exchange ratio, and oxygen consumption were measured using a calibrated mobile gas analysis system and a heart rate monitor. For reliability, intraclass correlation coefficients (ICCs), SE of measurement, smallest detectable change for total covered distance, minute work, and heart rate were calculated. Physiologic response during the 6MPT was expressed as percentage of maximal values achieved during the shuttle ride test.

Results. The ICCs for total distance and minute work were excellent (0.95 and 0.97, respectively), and the ICC for heart rate was good (0.81). The physiologic response during the 6MPT was 85% to 89% of maximal values, except for minute ventilation (70.6%).

Conclusions. For most youth with SB who use a wheelchair for mobility or sports participation, the 6MPT is a reliable, functional performance test on a vigorous level of exercise.

Impact. This is the first study to investigate physiologic response during the 6MPT in youth (with SB) who are wheelchair using. Clinicians can use the 6MPT to evaluate functional performance and help design effective exercise programs for youth with SB who are wheelchair using.

Spina bifida (SB) is the most common form of neural tube defects, with a worldwide prevalence ranging from 43.6 to 59.8 per 100,000 live births.[1,2] At present, 60% to 80% of children with SB are expected to reach adulthood.[3–6] Depending on the level of lesions and type of SB, children experience different problems in their sensory and motor functions, cognition, and bowel and bladder control.[7] Because of these problems, youth with SB encounter difficulties in everyday activities, such as having low levels of physical activity and physical fitness.[8–10] Despite the common occurrence of lower levels of physical activity and physical fitness, there are very few tests available that can measure and assess these levels in youth with SB.

The 6-minute walk test (6MWT) is the most widely used test for measuring functional aerobic performance in the ambulatory pediatric population.[11] It is a well-standardized, nonsophisticated, and safe test.[12–14] The test-retest reliability and measurement error of the 6MWT vary greatly among different chronic (pediatric) conditions (eg, fair in children with cystic fibrosis, excellent in children with cerebral palsy).[15–17] In ambulatory youth with SB, the 6MWT is a reliable, recommended measurement to assess functional ambulatory performance.[18] However, the construct of the 6MWT seems to depend on the disease severity of the SB.[15] Approximately 50% of youth with SB depend on a wheelchair for daily mobility, activities outside, or for long distances.[19] Despite this high percentage of wheelchair users, there is limited information regarding assessments for youth who have SB and use a wheelchair.

Verschuren et al developed the 6-minute push test (6MPT) for youth who are wheelchair using as an alternative for the 6MWT in the ambulatory population.[20] They stated that the 6MPT is a reliable, functional test for youth with cerebral palsy (CP) who are wheelchair using. At the same time, they found a large variability in physiologic stress during the 6MPT.[20] Therefore the aim of this study was 2-fold: to evaluate the test-retest reliability of the 6MPT and to determine the physiologic response during the 6MPT in youngsters with SB who are wheelchair using.

Methods

Participants

This cross-sectional study is part of the larger "Let's Ride ... study," focusing on physical fitness and physical activity in youth with SB who are wheelchair using.[10] Participants were recruited using a flyer distributed by different communities, several outpatients' services, and rehabilitation centers throughout the Netherlands.

To be included in this study, participants had to be diagnosed with SB; had to use a manual wheelchair for mobility in daily life, long distances, and/or for sports; were between 5 and 18 years old during enrollment; and

had to be able to follow simple instructions regarding testing. Exclusion criteria were: (medical) events that might intervene with the outcome of the testing such as illness; change in the wheelchair during the testing period; and/or a medical status that did not allow maximal exercise testing such as acute illness, less than 4 weeks postsurgery, or shunt malfunction. All parents and participants aged 12 years or older gave written informed consent before testing procedures were started.[10]

Procedure

The Medical Ethical Committee of the University Medical Center Utrecht (Utrecht, the Netherlands) approved all parts of the "Let's Ride ... study" procedures (numbers 11-557).[10] For that study, participants were split into 2 groups before testing. This was done to protect the participants from too many tests during the 4 test days. The first group performed the 6MPT twice, whereas the other group performed other tests twice. In advance, we included 50% (n = 26) of all youngsters (n = 53) in the group that had to perform the 6MPT twice.

Measurements took place in the gymnasium of the HU University of Applied Sciences Utrecht or in a gymnasium at a location near to the participants. All youngsters had to perform the 6MPT and shuttle ride test (SRiT) once. To determine the test-retest reliability of the 6MPT, 26 participants performed a retest of the 6MPT within 2 weeks following the first round of tests. For this group, the testing conditions were similar during the 2 test days: same floor, same tire pressure (the specific maximum pressure that was allowed for that type of wheelchair), and same own wheelchair. Demographics (sex, age, health status, medical status, use and type of wheelchair) were obtained by a standard questionnaire filled out by the participants and/or their parents prior to testing. The weight of the youngster and the wheelchair was measured using an electronic wheelchair scale (Kern MWS-300K100M; Kern & Sohn GmbH, Balingen, Germany). In addition, the height was measured using the arm span of the participant, because contractures in the lower extremities are a common problem in youth with SB who are wheelchair using. The arm span was measured from one middle fingertip to the other.[21–24] The body mass index was multiplied by 0.95 for midlumbar lesions and by 0.90 for high lumbar/thoracic lesions.[24] To determine the ambulation level, the modified Hoffer classification was used.[25]

Exercise Testing

All participants performed the 6MPT to determine functional wheelchair driving, and the SRiT for maximal exercise testing. During both tests, the heart rate (HR) was measured using an HR monitor (MiniCardio; Hosand Technologies Srl, Verbania, Italy). The HR monitor was attached to the chest using electrocardiogram electrodes (H99SG; Kendall, Covidien, Ireland). To measure minute

ventilation (VE), respiratory exchange ratio (RER, calculated as oxygen consumption divided by carbon dioxide production), and oxygen consumption (Vo_2), a calibrated gas analysis system (METAMAX 3B; CORTEX Biophysik GmbH, Leipzig, Germany) was used. The METAMAX is a valid and reliable instrument to measure gas exchange parameters in youth who are wheelchair using during exercise testing.[26–28] Original data from the METAMAX were prepared for analysis using a 10-second moving average interval.[16]

Both the 6MPT and SRiT took place on the same day. The participants started with the 6MPT, followed by a period of rest (at least 15 minutes), until cardiopulmonary values dropped to their values in rest. After that, all participants performed the SRiT.

The participants who had to perform a retest of the 6MPT for the reliability part of the study performed the 6MPT for a second time within a period of 2 weeks after the first test.

6-Minute Push Test
The 6MPT was used to determine the distance a participant could propel as far as possible, on a flat, hard surface, within 6 minutes. The distance between the 2 cones (used as turning points) was 10 m.[20] Marking tape was placed at 1-m intervals. Before starting, the participants sat still for 5 minutes in their wheelchair as the resting phase. Standardized instructions were used before and during testing.[20] The participants were, if necessary, allowed to slow down, stop, and rest during testing, but they were instructed to resume propelling as soon as possible. Participants used their own wheelchair during testing. Peak Vo_2, peak RER, and peak VE were calculated as the average value over the highest 30 seconds during the (first) 6MPT. Peak HR was defined as the highest value reached during the (first) 6MPT. By counting the number of times the participant passed the start line, we calculated the total covered distance using the following formula: total distance (meters) covered in the 6MPT = (number of times passed the start line × 20) + distance past the start line. The value for 6 minutes of work was calculated[29] as total distance covered in the 6MPT × weight of the (youngster + wheelchair).

Shuttle Ride Test
The SRiT is a valid and reliable maximal incremental field-based exercise test, for the assessment of aerobic fitness (peak Vo_2) in youth with SB who are wheelchair using when using a mobile gas analysis system.[30] Participants were instructed to move back and forth between 2 lines 10 m apart. They were instructed to cross the lines with their front wheels and then turn 180°. The starting speed was 2.0 km/h, and the speed increased by 0.25 km/h every minute.[31] The speed was determined by an audio signal (beep) that was played by a standard CD player. The test finished when a participant was more than

1.5 m away from the line, on 2 consecutive paced signals (could not keep up the pace), or when a participant got exhausted. Participants used their own wheelchair during testing and were encouraged to achieve their maximal effort. It is unclear if objective criteria for maximal effort (peak RER > 0.99; peak HR > 180/min or Vo_2 plateau) are also applicable in youth who are wheelchair using.[30] Therefore the data of the SRiT were included for analysis if subjective criteria of maximal effort were met (signs of intense effort such as sweating, facial blushing, or clear unwillingness to continue despite encouragement).[32,33] Peak Vo_2, peak RER, and peak VE were calculated as the average value over the highest 30 seconds during the SRiT. Peak HR was defined as the highest value reached during the test. In addition to these cardiopulmonary parameters, the total number of achieved shuttles was recorded.

Data Analysis
Before data collection, a sample size estimation was performed. Using the method of Shrout and Fleiss,[34] a sample size of 25 will, with 95% probability, result in a sample intraclass correlation coefficient (ICC) greater than 0.75 when the true ICC is as high as 0.85. This sample size estimation was based on the reliability part of the study. Statistical analysis was performed using SPSS version 21.0 for Mac (SPSS Inc, Chicago, Illinois). First, data were checked for normality using histograms, Q-Q plots, and Shapiro-Wilk tests. A visual interpretation of Bland-Altman plots[35] was performed to check for heteroscedasticity. After checking for normality and heteroscedasticity, test-retest reliability and physiologic response were determined.

Test-retest reliability of the 6MPT. Reliability consists of reliability and measurement error.[36] For analyzing test-retest reliability, the ICC was calculated using model 2.1.A of Shrout and Fleiss,[34] as follows: $ICC_{agreement} = \sigma^2_{participant}/(\sigma^2_{participant} + \sigma^2_{observer} + \sigma^2_{residual})$, in which $\sigma_{participant}$ represents the variability between participants, $\sigma_{observer}$ represents the variability between observers, and $\sigma_{residual}$ accounts for the random error.[37]

In clinical practice, an ICC greater than 0.90 is considered to be good.[37–40] Coefficients below 0.50 represent poor reliability.[41] For clinical practice, measurement error is more important, because this is used to determine true changes in a single patient. Therefore the SE of measurement agreement ($SEM_{agreement}$) and smallest detectable change agreement ($SDC_{agreement}$) were calculated. $SEM_{agreement}$ was calculated as $\sqrt{(\sigma^2_m + \sigma^2_{residual})}$, in which σ^2_m accounts for the systematic errors between both measurements, and $\sigma^2_{residual}$ accounts for the random error.[38,40] The $SDC_{agreement}$ was calculated as $1.96 \times \sqrt{2} \times SEM_{agreement}$.[38,40] For interpretation, both $SEM_{agreement}$ and $SDC_{agreement}$ were calculated as percentages of their

mean scores. Because no expensive calibrated gas analysis system is needed to measure HR, covered distance, and the value for 6 minutes of work, these variables are easy to administer in clinical practice. Therefore, we only calculate test-retest reliability for these 3 variables.

Physiologic response during the 6MPT. The different cardiopulmonary parameters (HR, VE, RER, Vo_2) obtained during the 6MPT were, for each participant individually, expressed as percentages of their peak values obtained during the maximal exercise test (SRiT). By doing so, we were able to standardize the results of the 6MPT. For the participants who performed a retest after 2 weeks, the cardiopulmonary parameters of the first 6MPT were used. Exercise intensity of the 6MPT was finally expressed on the basis of the percentage of HR_{max} for HR (<57% = very light; 57%–63% = light; 64%–76% = moderate; 77%–95% = vigorous; >95% = nearly maximal to maximal).[42] For the other cardiopulmonary parameters, the percentage of Vo_{2max} was used to express exercise intensity (<37% = very light; 37%–45% = light; 46%–63% = moderate; 64%–90% = vigorous; >90% = nearly maximal to maximal).[42]

For every single cardiopulmonary parameter and for speed, error bars were created to visualize their course during the 6 minutes. Data were expressed as mean values and their 95% CI intervals. To test minute-to-minute differences of all cardiopulmonary parameters, a repeated measurement analysis of variance (ANOVA) was used.[38,43] To overcome the problem of multiple testing, a post hoc Bonferroni correction was performed.[44] P values were considered to be statistically significant if they were less than $\alpha/4 = .0125$ ($\alpha = .05$).

Role of the Funding Source

This study was funded by SIA-RAAK (project no. 2011–12–35P), which had no role in the design, data collection, analysis, or interpretation, or reporting of this work, or the decision to submit the work for publication.

Results

The characteristics of the participants (n = 53) are described in Table 1. Their mean age during enrollment was 13 years 7 months (SD = 3 y 10 mo; range = 5–19 y). The majority of the participants had a lumbar lesion and were not ambulatory according to the modified Hoffer classification.[19] Forty-five participants (84.9%) successfully completed both the 6MPT and the SRiT. For 3 participants, the 6MPT was too difficult to complete. These 3 participants were all younger than 6 years of age. In 2 other youngsters, there were problems with the METAMAX during the 6MPT. Three youngsters failed to meet the subjective criteria for maximal effort during the SRiT and were therefore excluded.
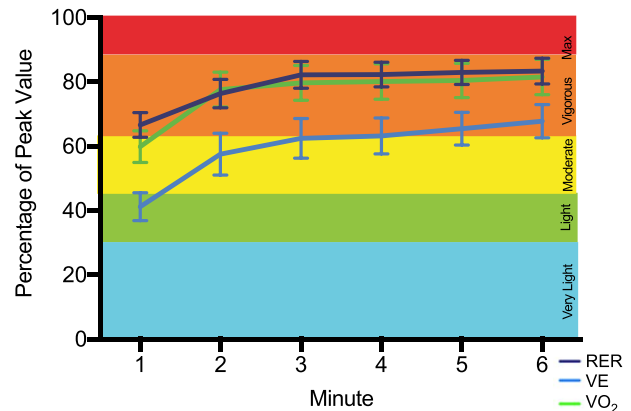
Physiologic Response

Figure 1.
Course of oxygen consumption (Vo_2; shown by green line), respiratory exchange ratio (RER; shown by dark blue line), and minute ventilation (VE; shown by light blue line) during the 6-minute push test (6MPT), expressed as a percentage of peak Vo_2 (Vo_{2peak}), peak RER (RER_{peak}), and peak VE (VE_{peak}), respectively, during a maximal exercise test (shuttle ride test [SRiT]). Error bars show 95% CIs.

Reliability of the 6MPT

Test-retest reliability statistics are shown in Table 2. A total of 26 participants completed the 6MPT twice. The results for HR are based on 21 children because of dysfunction of the HR monitor in 5 children. The ICC for total covered distance, 0.95 (95% CI = 0.83–0.98), and the value for 6 minutes of work, 0.97 (95% CI = 0.89–0.99), were excellent. The ICC for HR, 0.81 (95% CI = 0.53–0.92), was good. The SDCs were about 15% to 25% of their mean scores. The SDCs were 23.5 beats/min for HR, 60.7 m for total covered distance, and 7.45 kg/km for the value for 6 minutes of work.

Physiologic Response During the 6MPT

The mean peak values for all cardiopulmonary parameters during the 6MPT, except VE, were 85% to 89% of maximal exercise. For VE, this percentage was 70.6%. Descriptive statistics for both the SRiT and the 6MPT are presented in Tables 3 and 4. Figures 1 and 2 show the course of the (cardiopulmonary) parameters during the 6MPT.

During the 6MPT, HR increased from 72.8% to 83.5% of peak HR during the SRiT. Minute-to-minute differences for HR during 6MPT were not statistically significant except for the difference between minutes 1 and 2 ($P < .001$). The absolute and relative Vo_2 during 6MPT increased by 23.1% (58.8%–81.9%). The difference for Vo_2 during 6MPT between the first and second minute was significant ($P < .001$). After that, Vo_2 during 6MPT stabilized. VE during 6MPT increased from 41.2% to 67.8%. The minute-to-minute differences for VE during 6MPT were

Table 1.
Characteristics of Participants[a]

Characteristic	All Participants (n = 53)	Participants With a Physiologic Response (n = 45)	Participants in the Reliability Study (n = 26)
Sex (no. of boys/no. of girls)	32/21	27/18	12/14
Level of lesion			
Thoracic	11 (20.7)	8 (17.8)	5 (19.2)
Lumbar	41 (77.4)	36 (80.0)	20 (76.9)
Sacral	1 (1.9)	1 (2.2)	1 (3.9)
Ambulation level[28]			
Community ambulation	5 (9.4)	5 (11.1)	2 (7.7)
Household ambulation	6 (11.3)	5 (11.1)	3 (11.5)
Therapeutic ambulation	4 (7.5)	4 (8.9)	2 (7.7)
No ambulation	38 (71.7)	31 (68.9)	19 (73.1)
Age, mean (SD)	13 y 7 mo (3 y 10 mo)	14 y 4 mo (3 y 5 mo)	14 y 9 mo (3 y 7 mo)
Body mass, kg, mean (SD)	48.1 (18.9)	52.0 (17.3)	52.7 (17.0)
Arm span, cm, mean (SD)	154.4 (21.7)	159.6 (18.1)	156.4 (17.3)
BMI, kg/m^2, mean (SD)[24]	19.5 (5.8)	20.2 (5.9)	21.5 (6.9)
Underweight[45,46]	16 (30.2)	13 (28.9)	6 (23.1)
Normal weight[45,46]	25 (47.2)	20 (44.4)	11 (42.3)
Overweight[45,46]	6 (11.3)	6 (13.3)	4 (15.4)
Obese[45,46]	6 (11.3)	6 (13.3)	5 (19.2)

[a] Data are reported as number (percentage) of participants, unless otherwise indicated. BMI = body mass index.

statistically significant for the differences between minutes 1 and 2 ($P < .001$) and minutes 2 and 3 ($P < .001$). RER during 6MPT increased significantly during the first 2 minutes ($P < .001$). After that, RER during 6MPT stabilized at about 82% of peak RER during SRiT.

In contrast to the physiologic responses previously mentioned, the speed decreased significantly between minutes 1 and 2 ($P < .001$), stabilized until the fifth minute, and significantly increased in the last minute ($P < .001$). Maximum speed during 6MPT was, on average, 89.3% of maximum speed during the SRiT. The mean covered distance in 6 minutes was 418.0 m (SD = 103.1 m; range = 160–589 m).

Discussion

The aim of this study was 2-fold: to determine the test-retest reliability and the physiologic response during the 6MPT for youth with SB who are wheelchair using.

Reliability

Reliability of the 6MPT in youth with SB who are wheelchair using was excellent for total covered distance. A youngster has to cover a distance of at least 60.7 m, more or less, during retest of the 6MPT to conclude that functional performance level increased or decreased

between test and retest. Although this seems to be a considerable distance, it is comparable with the SDC for total covered distance during the 6MPT in youth with CP who are wheelchair using (60.7 m compared with 57.9 m, respectively).[20] However, as a percentage of the mean the SDC in youth with SB was lower than that in their peers with CP (14.7% compared with 21.7%).[20] This indicates that our study population (youth with SB) covered a higher total distance in 6 minutes than their peers with CP. A possible reason could be that youth with CP experience dysfunction in the upper extremities more often than youth with SB do.[47–49] The SDC for HR was high (23.5 beats/min), but also comparable with the SDC of HR during the SRiT in youth with SB who are wheelchair using.[30]

The mean total covered distance during the second 6MPT (retest) was, in our study, significantly lower than during the first 6MPT (−25 m). Unfortunately, we cannot explain this difference and are not sure if it is clinically relevant. Our participants were not offered a practice session. We recommend that physical therapists perform a practice session in clinical practice so that the youngster will get more familiar with the 6MPT. To provide a deeper insight into the interpretation of the SDC of the total covered distance during the 6MPT and the clinical relevance, the minimal important change should be obtained.[33,50]

Table 2.
Test-Retest Reliability Statistics for the 6-Minute Push Test (6MPT)[a]

Parameter	Test		Retest		ICC_agreement[b] (95% CI)	SEM	SEM, % of Mean	SDC	SDC, % of Mean
	Mean	SD	Mean	SD					
Heart rate[c]	158 bpm	19 bpm	152 bpm	20 bpm	0.81 (0.53–0.92)	8.5 bpm	5.5	23.5 bpm	15.2
Total distance	424.9 m	101.5 m	406.7 m	100.2 m	0.95 (0.83–0.98)	21.9 m	5.3	60.7 m	14.6
6 min of work	30.5 kg/km	8.2 kg/km	29.4 kg/km	8.4 kg/km	0.97 (0.89–0.99)	1.41 kg/km	4.7	7.45 kg/km	24.9

[a] bpm = beats/min; ICC_agreement = intraclass correlation coefficient agreement; SDC = smallest detectable change; SEM = standard error of measurement.
[b] From model 2.1.A of Shrout and Fleiss.[34]
[c] n = 21; data were missing because of a dysfunctioning heart rate monitor (5 occurrences).
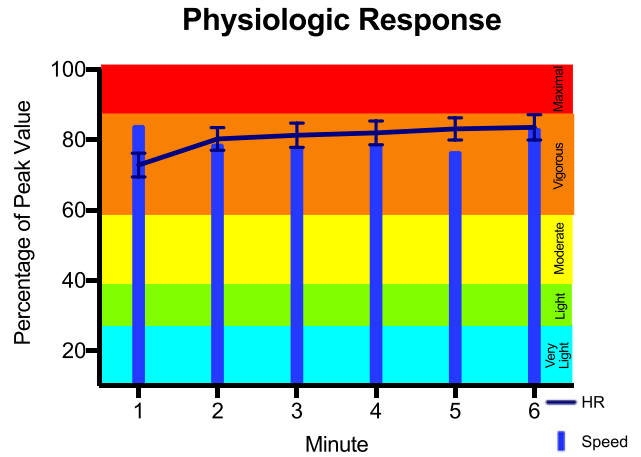
Physiologic Response

Figure 2.
Course of heart rate (HR; dark blue line) and speed (blue columns) during the 6-minute push test (6MPT), expressed as a percentage of peak HR (HR_{peak}) and peak speed ($speed_{peak}$), respectively, during a maximal exercise test (shuttle ride test [SRiT]). Error bars show the 95% CIs of HR.

Physiologic Response

To our knowledge, this is the first study to investigate physiologic response during the 6MPT in youth (with SB) who are wheelchair using. Our results indicate that the 6MPT is a vigorous functional performance test for youth with SB who are wheelchair using.[42] A previous study in the ambulatory population with SB, conducted by de Groot et al,[51] showed that the 6MWT is a vigorous functional performance test for these youth. This finding probably indicates that the cardiopulmonary stress during the 6MPT in youth who have SB and are not ambulatory is equal to the cardiopulmonary stress during the 6MWT in youth who are ambulatory. Moreover, the physiologic response that we found is comparable to the physiologic response in the ambulatory youth (mean age = 13 y 3 mo) with juvenile idiopathic arthritis during the 6MWT.[52] It is unclear whether the 6MPT is suitable for youth with other disabilities who are wheelchair using. Because measurement errors of the 6MWT vary greatly between different pediatric chronic conditions, we believe that this variation could be similar in youth who are not ambulatory and thus suggest further research in youth who do not have SB and are not ambulatory.[15]

The large range that we found for HR during the 6MPT and Vo_2 during the 6MPT indicates that for some youngsters with SB who are wheelchair using the 6MPT is a (nearly) maximal performance test, whereas for others the 6MPT is hardly a physiologically demanding test.[42] A possible explanation for this could be that the functional performance of manual wheelchair users is a result of 3 basic aspects: the user, the technical and biomechanical aspects of the wheelchair, and the wheelchair-user interaction. This wheelchair-user interaction will

Table 3.
Physiologic Responses During the Maximal Exercise Test (SRiT) and 6MPT and Percentages Achieved During the 6MPT[a]

Parameter	SRiT		6MPT		6MPT Percentages[b]	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Absolute Vo_{2peak},[c] L/min	1.18 (0.41)	0.36-2.10	1.03 (0.45)	0.34-2.06	86.4 (19.4)	34-135
Relative Vo_{2peak},[c] L/kg/min	23.26 (6.01)	11.33-34.33	19.85 (6.46)	7.29-34.82	86.0 (18.5)	34-120
Peak heart rate,[d] beats/min	183 (17)	139-208	157 (19)	122-205	86.2 (9)	67-99
Peak respiratory exchange ratio[e]	1.28 (0.20)	1.01-1.88	1.09 (0.15)	0.84-1.58	86.6 (12.6)	49-118
Peak minute ventilation,[c] L/min	55.3 (22.1)	12.7-105.5	38.9 (18.7)	11.3-89.6	70.6 (18.3)	33-116
Peak speed, km/h	5.20 (1.02)	2.63-6.88	4.65 (1.17)[f]	2.04-6.90[f]	89.3 (12.3)[f]	63-115[f]

[a] 6MPT = 6-minute push test; SRiT = shuttle ride test; Vo_{2peak} = peak oxygen consumption.

[b] 6MPT percentages were calculated separately for each participant as (peak heart rate during the 6MPT/peak heart rate during the SRiT) × 100.

[c] n = 41; data were missing because a youngster did not wear the METAMAX (CORTEX Biophysik GmbH, Leipzig, Germany) during the 6MPT, the SRiT, or both (2 occurrences) and because of dysfunction of the METAMAX (2 occurrences).

[d] n = 32; data were missing because of dysfunction of a heart rate monitor or the METAMAX during the 6MPT or the SRiT (11 occurrences) and because a youngster did not wear the METAMAX during the 6MPT, the SRiT, or both (2 occurrences).

[e] n = 40; data were missing because a youngster did not wear the METAMAX during the 6MPT, the SRiT, or both (2 occurrences) and because of dysfunction of the METAMAX (3 occurrences).

[f] n = 44; data were missing because a youngster did not complete the 6MPT because of dysfunction of the METAMAX (1 occurrence).

Table 4.
Physiologic Responses During the 6-Minute Push Test (6MPT) Minute to Minute[a]

Parameter	Mean 6MPT Percentages[b]					
	Minute 1	Minute 2	Minute 3	Minute 4	Minute 5	Minute 6
Absolute Vo_{2peak},[c] L/min	58.8	77.3	79.1	80.2	80.9	81.9
Heart rate,[d] beats/min	72.8	80.3	81.3	81.9	83.1	83.5
Respiratory exchange ratio[e]	66.6	76.4	82.2	82.3	82.9	83.4
Minute ventilation,[c] L/min	41.2	58.6	62.4	63.2	65.4	67.8
Speed,[f] km/h	84.2	78.9	77.9	78.6	76.8	83.4

[a] Vo_{2peak} = peak oxygen consumption.

[b] 6MPT percentages were calculated separately for each participant as (heart rate during the 6MPT/heart rate during the shuttle ride test [SRiT]) × 100.

[c] n = 41; data were missing because a youngster did not wear the METAMAX (CORTEX Biophysik GmbH, Leipzig, Germany) during the 6MPT, the SRiT, or both (2 occurrences) and because of dysfunction of the METAMAX (2 occurrences).

[d] n = 32; data were missing because of dysfunction of a heart rate monitor or the METAMAX during the 6MPT or the SRiT (11 occurrences) and because a youngster did not wear the METAMAX during the 6MPT, the SRiT, or both (2 occurrences).

[e] n = 40; data were missing because a youngster did not wear the METAMAX during the 6MPT, the SRiT, or both (2 occurrences) and because of dysfunction of the METAMAX (3 occurrences).

[f] n = 44; data were missing because a youngster did not complete the 6MPT because of dysfunction of the METAMAX (1 occurrence).

determine the overall efficiency of power transfer from the user to the wheelchair.[53,54] Unfortunately, we were not able to take into account all the different physical, technical, and biomechanical aspects.

The protocol of the 6MWT prescribes that running is not allowed. This instruction is difficult to translate to situations in which a wheelchair is used because there is no equivalent of running in wheelchair propulsion. We used the following instruction: "Try to achieve a covered distance as far as possible in 6 minutes." Some youngsters performed all out during the 6MPT, whereas others barely made any effort. Therefore, we expect that propulsion speed can also be influenced by the motivation of the youngster.

In addition, for some youngsters, especially for those under 10 years of age and those with a cognitive impairment, it was very difficult to estimate how long a time frame of 6 minutes lasted. Therefore pediatric physical therapists have to be aware of this when using the 6MPT for these children. We observed a typical pacing strategy in our participants: the speed was faster during the first and last minute of the test compared with the 4 minutes in the middle.

For evaluation purposes, using the total covered distance instead of HR is recommended because of the better reliability of total covered distance. A physical therapist might use the HR to determine the physiologic demand of the 6MPT for a youngster with SB who is wheelchair using, but the total covered distance is more important for the evaluation of the functional performance of youngsters with SB who are wheelchair using.

There are several weaknesses and strengths in this study. One of our limitations is that we could not explain the difference in cardiopulmonary demands between the participants, because we did not evaluate all possible different influencing aspects (eg, propulsion technique, fit of the wheelchair, muscle strength, level of lesion, ambulation level).[20,48] Second, the problems we had with the HR registration, leading to missing HR data in 11 of 45 youngsters, was another important limitation. These missing data are a substantial part of the population that was tested, which could influence the mean HR_{peak}, the course of HR during the 6MPT, and the test-retest reliability of HR. It seems that the electrocardiogram electrodes we used during the first measurements caused the problems in HR registration. Because of that, after the first measurements, we changed to the electrocardiogram electrodes as described in "Methods" above. These electrodes would be recommended to replicate this study.

A strength of our study was that we included youngsters with SB on different levels, with different ages, and with various cognitive levels. This heterogeneous sample is comparable to the clinical population of youngsters with SB. Consequently, the results of this study can be well generalized to clinical practice.

Future Research
The impact of the wheelchair-user interaction and cognition when using the 6MPT in youth with SB who are wheelchair using, might be addressed in future research. It would be interesting to investigate the relationship between the age of a child, their (non-) verbal cognitive development, and their functional performance. Because measurement error of the 6MWT varies greatly among different chronic pediatric conditions,[15–17] we recommend obtaining the measurement error of the 6MPT in various populations who use wheelchairs.

Furthermore, the development of reference values for the 6MPT will help physical therapists to determine the level of functional performance of youngsters with a disability who are wheelchair using in relation to their peers.

Conclusion
The reliability of total covered distance during the 6MPT in youth with SB who are wheelchair using seems to be excellent with an SDC of 60 m, whereas the reliability for HR is good. Therefore, physical therapists are recommended to use the total covered distance in 6 minutes to determine and evaluate the level of functional performance in youth with SB who are wheelchair using. The intensity of the 6MPT varied greatly among the study population. Consequently, HR can be used to determine exercise intensity for an individual youngster. For most youngsters with SB who use a wheelchair for mobility in daily life or for sports, the 6MPT is a reliable, vigorous, functional performance test.

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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