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ORIGINAL RESEARCH

Validity and Reliability of Skill-Related Fitness Tests for Wheelchair-Using Youth With Spina Bifida

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Abstract

Objectives: To determine content validity of the Muscle Power Sprint Test (MPST), and construct validity and reliability of the MPST, 10×5 Meter Sprint Test (10×5MST), slalom test, and One Stroke Push Test (1SPT) in wheelchair-using youth with spina bifida (SB).

Design: Clinimetric study.

Setting: Rehabilitation centers, SB outpatient services, and private practices.

Participants: A convenience sample of children and adolescents (N=53; 32 boys, 21 girls; age range, 5−19y) with SB who use a manual wheelchair. Participants were recruited through rehabilitation centers, SB outpatient services, pediatric physical therapists, and the BOSK (Association of Physically Disabled Persons and their Parents).

Interventions: Not applicable.

Main Outcome Measures: Construct validity of the MPST was determined by comparing results with the arm-cranking Wingate Anaerobic Test (WAnT) using paired *t* tests and Pearson correlation coefficients, while content validity was assessed using time-based criteria for anaerobic testing. Construct validity of the 10×5MST, slalom test, and 1SPT was analyzed by hypothesis testing using Pearson correlation coefficients and multiple regression. For reliability, intraclass correlation coefficients (ICCs) and smallest detectable changes (SDCs) were calculated.

Results: For the MPST, the mean ± SD exercise time of 4 sprints was 28.1±6.6 seconds. Correlations between the MPST and arm-cranking WAnT were high (r>.72, P<.01). Excellent correlations were found between the 10×5MST and slalom test (r=.93, P<.01), while correlations between the 10×5MST or slalom test and MPST and 1SPT were moderate (r=−.56 to −.70; r=.56, P<.01). The variation of the 1SPT was explained for 38% by wheelchair mass (β=−.489) and total upper muscle strength (β=.420). All ICCs were excellent (ICCs>.95), but the SDCs varied widely.

Conclusions: The MPST is a valid and reliable test in wheelchair-using youth with SB for measuring anaerobic performance. The 10×5MST and slalom test are valid and reliable for measuring agility. For the 1SPT, both validity and reliability are questionable.

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Assessment and optimizing physical fitness in youth with chronic conditions such as spina bifida (SB) are important goals in pediatric rehabilitation.[1] About 50% of children with SB use a wheelchair as their main mobility, and a large number of ambulatory children use a wheelchair for community mobility or sports.[2,3] While several physical fitness tests have been developed for ambulatory youth with disabilities, evidence for wheelchair-using youth is lacking.[4,5] Skill-related fitness is part of physical fitness as defined by Caspersen et al,[6] and consists of power, speed, agility, coordination, balance, and reaction time. In daily life of wheelchair-using youth, skill-related fitness is reflected in activities such as playing outside or playing wheelchair sports.[7] Since participation in outside play and sports is an essential goal in pediatric rehabilitation, assessment of skill-related fitness

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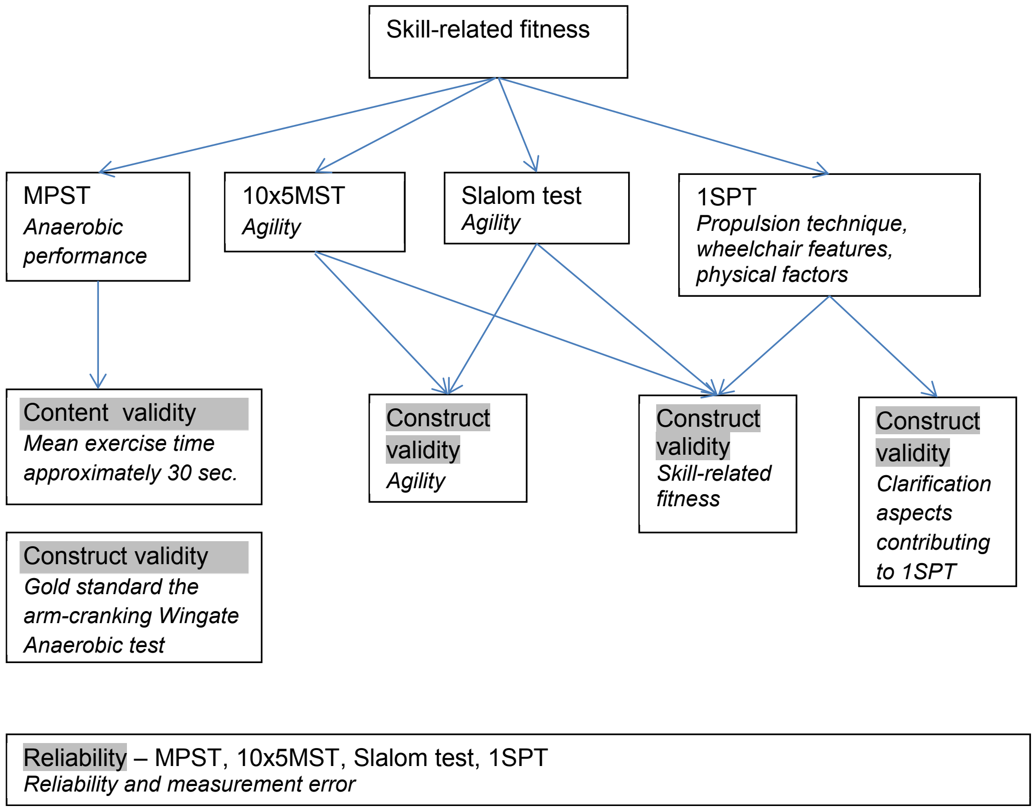

Fig 1 Overview of testing for field-based skill-related fitness tests in wheelchair-using youth with SB.

is important. This assessment enhances clinical reasoning and supports evaluation of training programs.

Field-based testing does not require expensive equipment, is task specific, and children use their own wheelchair, which is of great importance because it takes into account the wheelchair-user interface integration.[4,8-12] For wheelchair-using people, several field-based tests have been developed in which aspects of skill-related fitness, such as power, speed, agility, and coordination, play an important role.

The Muscle Power Sprint Test (MPST), combining both power and speed, measures anaerobic performance during 15-m sprints.[5,9,11,13] Content and construct validity of the MPST have been established for children with cerebral palsy (CP).[9,11,13] Content validity is defined as "the degree to which the content of a measurement instrument is an adequate reflection of the construct to be measured."[14(p743)] Anaerobic performance contains short-term high-intensity exercise, with adenosine triphosphate, phosphocreatine, and glycogen being the dominant fuel sources.[13,15] Therefore, high-intensity exercise should be performed for a maximum of 30 seconds. In ambulatory youth with CP this results in 6 sprints, while for wheelchair-using youth with CP the total number of sprints is 3.[9,11,13] Construct validity is "the degree to which the scores of a measurement instrument are consistent with hypotheses, for instance relationships to scores of other instruments."[14(p743)] The arm-cranking Wingate Anaerobic Test (WAnT) is the criterion standard laboratory assessment for anaerobic capacity in wheelchair-using people and is thus suitable to determine the construct validity of the MPST.[15]

Agility refers to acceleration, deceleration, and turning and is reflected by the 10×5 Meter Sprint Test (10×5MST) and slalom test.[5,11,16] The One Stroke Push Test (1SPT) measures aspects of coordination (propelling technique) and also wheelchair features and physical factors (eg, strength).[10,17] No criterion standards are available for the 10×5MST, slalom test, and 1SPT. However, identifying the relationships between these different skill-related fitness tests contributes to clarification of the underlying constructs.

Reliability concerns "the degree to which the measurement is free from measurement error" and consists of both reliability and measurement error.[14(p743),18] While there is some evidence for validity and reliability of the MPST, 10×5MST, and 1SPT, evidence is lacking for wheelchair-using youth with SB. Therefore, the aims of this study were to determine (1) the content and construct validity of the MPST; (2) the construct validity of the 10×5MST, slalom test, and 1SPT; and (3) the reliability of the MPST, 10×5MST, slalom test, and 1SPT in wheelchair-using youth with SB.

Concerning content validity, we hypothesized that the total number of sprints of the original ambulatory version of the MPST (6 sprints)

List of abbreviations:

CP	**cerebral palsy**
ICC	**intraclass correlation coefficient**
MP	**mean power**
MPST	**Muscle Power Sprint Test**
1SPT	**One Stroke Push Test**
PP	**peak power**
SB	**spina bifida**
SDC	**smallest detectable change**
10×5MST	**10×5 Meter Sprint Test**
WAnT	**Wingate Anaerobic Test**

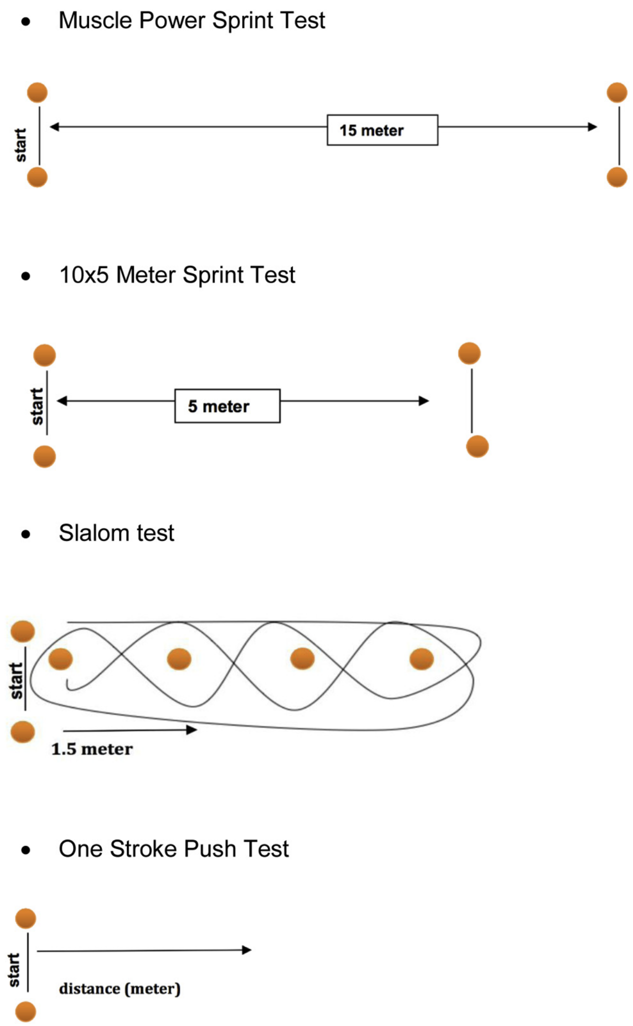

Fig 2 Overview of the field-based skill-related fitness tests.

should be adjusted to a lower number. For construct validity, we hypothesized high correlations between the MPST and the criterion standard laboratory assessment for anaerobic power, the arm-cranking WAnT. In addition, we hypothesized high to excellent correlations between the 10×5MST and slalom test, as both tests measure agility. Moderate correlations were expected between the 10×5MST or slalom test and the MPST and 1 SPT, since they all measure different yet related aspects of skill-related fitness. Moreover, we hypothesized that wheelchair features such as wheelchair mass and physical factors such as muscle strength contribute to the 1SPT.

Methods

The Medical Ethics Committee of the University Medical Center Utrecht, the Netherlands, approved the study procedures (no. 11-557). Parents, and the children aged ≥12 years signed informed consent.

Participants

This study is part of the larger "Let's Ride…study," focusing on fitness and physical activity in wheelchair-using youth with SB.[19] Recruitment and inclusion and exclusion criteria of the participants are described earlier in our validity and reliability study regarding aerobic fitness testing in the lab environment in wheelchair-using youth with SB.[19] Participants were recruited in the Netherlands and included if they had received a diagnosis of SB, were aged 5 to 18 years during enrollment, used a wheelchair, and were able to follow instructions.

Procedures

Figure 1 presents the clinimetric properties evaluated in this study. Participants were assessed twice (validity part) or 3 times (validity and reliability part), with 3 days to 1 week between testing moments. The tester was a pediatric physical therapist, and both the tester and the participants were unaware of previous results. Age, sex, type of SB, lesion level, use of wheelchair, and type of wheelchair were recorded through a standard questionnaire. An electronic wheelchair scale[a] was used to register body mass and wheelchair mass. Arm span length (middle fingertip to middle fingertip) was used as an indicator for height as recommended in wheelchair-using people, using nonstretchable tape.[20] Body mass index was calculated as body mass divided by the square of height, with an adjustment ×.95 for midlumbar lesions and ×.90 for high lumbar/thoracic lesions.[20]

Exercise testing

Both verbal instructions and demonstrations were provided using a standardized protocol, and included verbal encouragements throughout all tests to ensure maximal effort. Every test started with a habituation period during which participants were familiarized with the test, with 5 minutes of resting before starting the actual measurement. Figure 2 presents an overview of the skill-related fitness tests.

Muscle Power Sprint Test

Participants were instructed to propel a distance of 15m marked by 2 lines as fast as possible. This was repeated 6 times. Between every

Table 1 Participant characteristics (N=53)

Characteristics	Mean ± SD
Age	13y6mo ± 3y11mo
Body mass (kg)	47.9±18.9
Arm span length (m)	1.54±.22
Body mass index (kg/m^2)	22.6±6.6
Weight of wheelchair (kg)	19.6±7.0
	n (%)
Sex (male/female)	32/21 (60/40)
Type (open/closed)	49/4 (92/8)
Level of lesion[26]	
• Thoracic	7 (13)
• Lumbar	41 (77)
• Sacral	5 (10)
Ambulation level[27]	
• Community ambulatory	5 (9)
• Household ambulatory	6 (11)
• Therapeutic ambulatory	4 (8)
• Nonambulator	38 (72)

Table 2 Number of participants in the skill-related fitness tests in wheelchair-using youth with SB

	Test			Retest		
	n	Completed	Reason MD	n	Completed	Reason MD
WAnT	53	42 (79%)	5 (9%) not able to come to university; 6 (11%) limitations ergometer*	NA	NA	NA
MPST	53	53 (100%)	NA	38	38 (100%)	NA
10×5MST	53	48 (91%)	5 (9%) too difficult	37	32 (86%)	5 (14%) too difficult
Slalom test	53	51 (96%)	2 (4%) too difficult	38	34 (89%)	4 (11%) too difficult
1SPT	53	48 (91%)	1 (2%) too difficult; 4 (8%) lack of space	33	28 (85%)	1 (3%) too difficult; 4 (12%) lack of space

Abbreviations: MD, missing data; NA, not applicable.
* Ergometer proportions did not fit the participant.

sprint, participants had 10 seconds to turn and prepare. The main outcome measure was the manually recorded time per 15-m sprint (to .01s). Power output for each sprint was determined as follows:

Power = Total mass (Body mass + Wheelchair mass) × Distance^2/Time

The highest power is presented as peak power (PP), while the average power over the sprints is presented as mean power (MP).[11]

Arm-cranking WAnT

We used an electromagnetically braked arm ergometer[b] to perform the arm-cranking WAnT, while participants sat in their own wheelchair that was fixated to the floor. During the first 2 minutes (warmup phase), no breaking force was applied and participants had to crank at a comfortable speed. During the last 10 seconds of the warmup, a countdown was given to allow them to maximize their pace, after which a braking force of .26Nm/kg was immediately applied, and participants had to crank as fast as possible for 30 seconds.[11] Both PP (highest mechanical power) and MP (average power over 30s) were recorded with the fully computerized Lode Ergometry Manager Software.[11,15,c]

10×5 Meter Sprint Test

Participants were instructed to sprint and turn 10 times continuously as fast as possible, between 2 lines that were 5m apart. The main outcome measure was the manually recorded time (to .01s).[11]

Slalom test

Participants were instructed to slalom as fast as possible between 4 cones placed 1.5m apart. Participants had to turn at the end, sprint back, and repeat the same procedure once. The main outcome measure was the manually recorded time (to .01s).[16]

One Stroke Push Test

Participants had to cover as much distance as possible by using 1 push. The main outcome measure was the distance (in centimeters) measured from the starting line to the most anterior point of the front wheel furthest away. The mean distance of 3 trials was calculated.[10]

Muscle strength

Muscle strength of the upper extremities (shoulder abductors, elbow flexors and extensors, wrist dorsal flexors) was measured by the CITEC handheld dynamometer[d] using the break method according to Beenakker et al.[21] It is a reliable method for measuring muscle strength in youth with SB.[22] Total upper muscle strength was defined as the summed score of these 4 muscle groups.[21]

Statistical analysis

Before the data collection, a sample size estimation was performed. With the use of the method described by Shrout and Fleiss,[23] a sample size of 25 will, with 95% probability, result in a sample intraclass correlation coefficient (ICC) of >.75 (considered to be good) when the true ICC is as high as .85. This sample size estimation was based on the reliability part of the study.

Data were analyzed for normality using quantile-quantile plots, histograms, and scatterplots.

Content and construct validity of MPST

For content validity of the MPST, the number of sprints with a mean duration time close to 30 seconds was determined. Consequently, this number of sprints was used for calculating the MP and PP. Construct validity between the MPST and the arm-cranking WAnT was evaluated by Pearson correlation coefficients and paired *t* tests.

Construct validity of 10×5MST, slalom test, and 1SPT

Pearson correlation coefficients were used to determine construct validity between the MPST, 10×5MST, slalom test, and 1SPT. In addition, we analyzed the contribution of wheelchair features and physical factors to the distance covered during the 1SPT. First, linearity of relationships between the 1SPT and the independent variables

Table 3 Test results (paired *t* tests and Pearson correlation coefficients) of arm-cranking WAnT and MPST (construct validity)

			WAnT − MPST	
Power	WAnT (n=42)	MPST (n=53)	Diff. (Mean)	*r*
PP (W)	176.6±90.7 (35.9−436.6)	59.2±39.1 (5.0−143.4)	117.4*	.74*
MP (W)	100.8±56.6 (18.0−243.3)	54.0±36.1 (4.1−127.0)	46.8*	.88*

NOTE. Values are mean ± SD (range) or as otherwise indicated.
Abbreviations: Diff., difference; *r*, Pearson correlation coefficient.
* $P<.01$.

Table 4 Regression models for explained variance in distance covered during 1SPT

Variables	B	95% CI	β	Sig.	Adjusted R^2
Constant	16.639	12.416 to 20.861		.000	.210
Wheelchair mass	−0.360	−0.559 to −0.161	−.477	.001	
Constant	11.566	6.862 to 16.270		.000	.376
Wheelchair mass	−0.370	−0.547 to −0.161	−.489	.000	
Total upper muscle strength	0.010	0.004 to 0.015	.420	.001	

Abbreviations: CI, 95% confidence interval; Sig., significance.

"tire pressure," "wheelchair mass," "wheelchair mass + body mass," "body mass," "body mass index," "age," and "total muscle strength" were assessed with scatterplots. Second, univariate analyses were quantified with Pearson correlation coefficients to select a maximum of 4 independent variables in the multiple regression analyses, to ensure stability of the parameter estimates given the sample size. Subsequently, a forward stepwise multiple regression analysis was performed. Variables were included with a P value $<.05$ and excluded with a P value $>.1$.

Reliability

Reliability was analyzed by the ICC Shrout and Fleiss model 2.1.A.[18,24]

The standard error of measurement agreement and the smallest detectable change (SDC) were determined for the measurement error. The standard error of measurement agreement was calculated by $\sqrt{\sigma_m^2 + \sigma_{residual}^2}$, in which σ_m^2 represents the systematic errors between both measurements, and $\sigma_{residual}^2$ represents the random error.[18,24] The SDC was calculated by 1.96 * $\sqrt{2}$ * standard error of measurement agreement.[24] For interpretation, both the standard errors of measurement and SDCs were calculated as percentages of mean scores.

Data interpretation

Moderate correlations were defined as r=0.5 to 0.7, high correlations as r=0.7 to 0.9, and excellent correlations as r=0.9 to 1.0.[25] High correlations ($r \geq 0.7$) were required for establishing construct validity of the MPST compared with the arm-cranking WAnT. Moderate correlations were required for establishing construct validity of the 10×5MST, slalom test, and 1SPT. ICCs of 0.7 to 0.9 were defined as good, and ICCs >.90 were defined as excellent.[25]

Results

The total study population consisted of 53 participants (32 boys, 21 girls), with a mean age ± SD of 13.6±3.11 years. The total number of participants was much higher than the minimum of 25 participants as estimated, because this study was part of the larger "Let's Ride…study." In this larger study, all participants were assessed with several tests measuring fitness and physical activity, but only some of them participated in the reliability study of the skill-related fitness tests. Participants' age, sex, height, weight, body mass index,[20] wheelchair mass, type of lesion, level of lesion,[26] and ambulation level[27] are presented in table 1. Table 2 lists the reasons for missing data.

Content and construct validity of MPST

Concerning content validity, the mean ± SD exercise time for 6 sprints was 42.5±10.3 seconds. The cutoff point for 30 seconds was 4 sprints, with a mean ± SD of 28.1±6.6 seconds. Therefore, the calculations of MP and PP were based on 4 sprints.

For construct validity, significant high correlations were found between the arm-cranking WAnT and the MPST for both PP and MP (r>.74, P<.01). Moreover, the PP and MP were significantly lower in the MPST (mean PP, 59.2W; mean MP, 54.0W) compared with the arm-cranking WAnT (mean PP, 176.6W; mean MP, 100.8W; P<.01) (table 3).

Construct validity of 10×5MST, slalom test, and 1SPT

A significant excellent correlation (r=.93, P<.01) was found between the 10×5MST and slalom test. Significant (P<.01) moderate correlations were found between the 10×5MST and MPST (r=−.70), 10×5MST and 1SPT (r=−.56), slalom test and MPST (r=−.67), slalom test and 1SPT (r=−.60), and 1SPT and MPST (r=.56).

For explaining the variation in the 1SPT, significant (P<.01) moderate correlations between the 1SPT and wheelchair mass (r=.48) and total upper muscle strength (r=.41) were found. Relations with all other variables (tire pressure, wheelchair mass + body mass, body mass, body mass index, age) showed P>.05. Subsequently, sex, wheelchair mass, and total upper muscle strength were used as independent variables in the regression analyses. Wheelchair mass (β=−.489) and total upper muscle strength (β=.420) explained 38% of the variation in 1SPT distance (table 4). Heteroscedasticity and multicollinearity assumptions were not violated.

Table 5 Outcome reliability data

Test	Test	Retest	$ICC_{agreement}$	95% CI	$SEM_{agreement}$	SEM, % of Mean	SDC	SDC, % of Mean
MPST PP (W) (n=38)	59.2±39.05 (5.0−143.4)	60.6±48.1 (4.4−156.4)	.98	.96−.99	6.8	11	18.7	31.6
MPST MP (W) (n=38)	54.0±36.05 (4.1−127.0)	55.1±43.8 (3.5−141.2)	.98	.97−.99	5.4	10	15.0	27.8
10×5MST (s) (n=32)	43.4±8.9 (32.8−72.1)	43.0±8.4 (32.8−66.9)	.97	.93−.98	1.6	3.7	4.4	10.1
Slalom test (s) (n=34)	22.3±5.7 (16.1−39.9)	22.2±5.9 (15.7−42.1)	.97	.94−.98	1.0	4.5	2.7	12.1
1SPT (m) (n=28)	9.6±5.6 (1.76−26.6)	9.9±6.4 (1.78−26.44)	.95	.95−.99	1.4	14.5	3.9	40.6

NOTE. Values are mean ± SD (range) or as otherwise indicated.
Abbreviations: CI, confidence interval; SEM, standard error of measurement.

Reliability of MPST, 10×5MST, slalom test, and 1SPT

Reliability of the MPST, 10×5MST, slalom test, and 1SPT was high, with ICCs >.95. The SEMs varied from 3.7% (10×5MST) to 14.5% (1SPT) of the mean, with SDCs varying from 10.1% (10×5MST) to 40.6% (1SPT) of the mean (table 5).

Discussion

Validity

Content validity of the MPST as an outcome measure for anaerobic fitness (<30s) resulted in a total of 4 sprints as opposed to 3 sprints in wheelchair-using children with CP. Therefore, when the MPST is used for wheelchair-using youth with SB, it should be adapted to 4 sprints.

High correlations between the arm-cranking WAnT and the MPST supported evidence for good construct validity of the MPST, in line with data in youth with CP. At the same time, also in line with data in youth with CP, the MPST yielded significantly lower PP and MP than did the arm-cranking WAnT.[11] These differences might be explained by the differences in performance during both tests: continuous hand cycling during the arm-cranking WAnT versus intermittent propelling during the MPST. Furthermore, 6 participants from our study were not able to perform the arm-cranking WAnT because the ergometer proportions did not fit the participants, while all participants were able to perform the MPST. Moreover, the MPST is inexpensive and easy to administer, and therefore a good field-based alternative for the lab-based arm-cranking WAnT when measuring anaerobic performance in wheelchair-using youth with SB.

For construct validity, the excellent correlation between the 10×5MST and slalom test supports the hypothesis that both tests measure agility. In addition, the moderate correlations between the 10×5MST or slalom test and 1SPT and MPST support the hypothesis that all tests measure skill-related fitness. The negative correlations we found were as expected, as higher scores on the MPST and 1SPT and lower scores on the slalom test and 10×5MST indicate better performance. Since it was hypothesized that the 1SPT measures propelling technique, wheelchair features, and physical factors, we analyzed the contribution of various variables in relation to the distance measured. Wheelchair mass (wheelchair feature) explained 21% of the variation and seemed to be most important. Subsequently, total upper muscle strength (physical factor) also seemed to play an important role. However, both variables only explained about 38% of the variation. A limitation was the inability to measure propulsion technique in biomechanical terms and the friction between the wheel and the floor; these variables appear to be important aspects contributing to the distance covered during the 1SPT.[28,29] We are, however (to our knowledge), the first to try to understand what the 1SPT truly measures in wheelchair-using youth. Future research may be able to take these biomechanical aspects into account and provide more insight into the different factors that contribute to the distance covered in 1 stroke. For now, clinicians, parents/patients, and manufacturers should realize the importance of lightweight wheelchairs, besides upper muscle strength, since this seems to affect performance in skill-related fitness tests positively and thus in daily life activities.

Reliability

We found excellent ICCs, comparable with the ICCs found in wheelchair-using youth with CP.[5,11] However, the observed SDCs varied widely. These SDCs are important for clinicians because they provide information about the true change of an individual patient.[14] We expressed them as percentages of the mean scores found in our study because outcomes from intervention studies are lacking. SDCs ranged from acceptable for the 10×5MST and slalom test, to questionable for the MPST and relatively high for the 1SPT. For the MPST and 10×5MST, they seem to be comparable or slightly lower compared with those for wheelchair-using youth with CP.[11] However, the SDC of the 1SPT measured in this study was slightly higher compared with that for wheelchair-using youth with CP.[10] Future research should clarify the minimal clinically important change and responsiveness of all tests, to give more insight into the interpretation of the SDCs.

Study limitations

Certain limitations should be considered when interpreting the results of this study. First, no objective criteria were available to determine whether participants performed maximally during all tests. Second, the time taken to execute the MPST, 10×5MST, and slalom test was recorded manually, which can be a source of error. However, this manual recording of time is highly representative of clinical practice. In addition, test and retest were performed by the same tester, so only intrarater reliability can be interpreted. Clinics or rehabilitation centers are advised to determine the interrater reliability between therapists working at their clinic.

Conclusions

Regarding content validity, the MPST should be adapted to 4 sprints when used in wheelchair-using youth with SB. It shows good construct validity with the arm-cranking WAnT for measuring anaerobic performance. Even though reliability of the MPST is high, its clinical use is questionable because of large measurement errors.

The construct validity of the 10×5MST and slalom test is good. The reliability of the 10×5MST and slalom test is high, and both tests have an acceptable measurement error. Depending on individual patient goals, clinicians can choose which test to use for measuring agility.

The clinical use of the 1SPT is still questionable because the construct is unclear and measurement error seems quite large.

Suppliers

a. Kern MWS-300K100M; Kern & Sohn GmbH.
b. Lode Angio; Procare BV.
c. Lode Ergometry Manager Software; Procare BV.
d. CITEC handheld dynamometer; C.I.T. Technics—Center for Innovative Technics.

Keywords

Adolescent; Child; Exercise test; Rehabilitation; Spinal dysraphism; Wheelchairs

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