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ORIGINAL REPORT

ARM CRANKING VERSUS WHEELCHAIR PROPULSION FOR TESTING AEROBIC FITNESS IN CHILDREN WITH SPINA BIFIDA WHO ARE WHEELCHAIR DEPENDENT

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Objective: **To determine the best test performance and feasibility using a Graded Arm Cranking Test vs a Graded Wheelchair Propulsion Test in young people with spina bifida who use a wheelchair, and to determine the reliability of the best test.**
Design: **Validity and reliability study.**
Subjects: **Young people with spina bifida who use a wheelchair.**
Methods: **Physiological responses were measured during a Graded Arm Cranking Test and a Graded Wheelchair Propulsion Test using a heart rate monitor and calibrated mobile gas analysis system (Cortex Metamax). For validity, peak oxygen uptake (VO_{2peak}) and peak heart rate (HR_{peak}) were compared using paired *t*-tests. For reliability, the intra-class correlation coefficients, standard error of measurement, and standard detectable change were calculated.**
Results: **VO_{2peak} and HR_{peak} were higher during wheelchair propulsion compared with arm cranking (23.1 vs 19.5 ml/kg/min, $p=0.11$; 165 vs 150 beats/min, $p<0.05$). Reliability of wheelchair propulsion showed high intra-class correlation coefficients (ICCs) for both VO_{2peak} (ICC = 0.93) and HR_{peak} (ICC = 0.90).**
Conclusion: **This pilot study shows higher HR_{peak} and a tendency to higher VO_{2peak} in young people with spina bifida who are using a wheelchair when tested during wheelchair propulsion compared with arm cranking. Wheelchair propulsion showed good reliability. We recommend performing a wheelchair propulsion test for aerobic fitness testing in this population.**

Key words: child; spinal dysraphism; wheelchair; exercise; physical fitness.

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INTRODUCTION

Aerobic fitness is related to clustered cardiovascular disease risk factors in children and adolescents (1). Several studies have shown young people with disabilities to be less active and less fit compared with their peers (2–4). Furthermore, studies have reported that adolescents and young adults who use a wheelchair are more inactive and less fit than their peers who walk (5, 6). For example, in a study of young adults with spina bifida (SB) who use a wheelchair, 39% were classified as inactive, and 37% as extremely inactive (6). Thus, aerobic fitness testing in children and adolescents with disabilities has become an important issue in both research and clinical practice (2, 7–10).

Several studies have examined methods of testing aerobic fitness in children with disabilities who are ambulatory (2). However, the knowledge-base regarding aerobic fitness testing for children and adolescents who use a wheelchair is small. In aerobic fitness testing peak oxygen uptake (VO_{2peak}) is considered to be the single best indicator of the cardio-respiratory system. The gold standard for measuring VO_{2peak} is an incremental ergometer test with gas exchange until volitional exhaustion.

In wheelchair ergometry, arm cranking protocols are often used in aerobic fitness testing. However, a recent review of wheelchair testing in adults suggests that arm cranking protocols lack specificity to wheelchair propulsion and therefore questions the validity of these types of protocols (11). A recent study in young people with cerebral palsy observed that a field test using wheelchair propulsion yielded higher cardiorespiratory parameters compared with arm cranking. Therefore wheelchair propulsion might be a more appropriate way of testing children and adolescents who use a wheelchair (12).

To test aerobic fitness in children with neuromuscular disease, Bar-Or stated that "testing in the laboratory has the advantage (over field conditions) of better standardization". Bar-Or further emphasized that, in children with neuromuscular disease, assessment of the oxygen transport system, reduced muscle function (strength and endurance) and other limitations should be taken into account when developing a test to measure VO_{2peak} (13).

In preparation for a larger intervention study, using VO_{2peak} as 1 of the outcome measures, the aims of this pilot study were: (*i*) to investigate the best test performance and feasibility using a Graded Arm Cranking Test (GACT) vs a Graded Wheelchair Propulsion Test (GWPT) in the laboratory to measure VO_{2peak} in children and adolescents with SB who use a wheelchair, and

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(*ii*) to determine the reliability of the best test in young people with SB who use a wheelchair.

METHODS

This study is part of the larger *"Let's Ride…study"*, looking at fitness and physical activity in young people with SB. The present study comprised 2 parts: "a best test performance and feasibility study (study 1; study population 13 children)" and "a reliability study (study 2; study population 24 children)".

Subjects

Children and adolescents were recruited through the BOSK (the association for people with a physical disability and their parents in the Netherlands), paediatric physical therapists working with these children, and several rehabilitation centres and SB outpatient services in the Netherlands. Inclusion criteria were: age range 6–18 years at enrolment; a diagnosis of SB; using a manual wheelchair for daily life and/or sports; and able to follow test instructions. Parents, and children who were aged 12 years and over, had to sign informed consent. Children and adolescents were excluded if they had any (medical) events that might interfere with testing (e.g. a change of wheelchair during the testing period or any acute medical events).

The study was approved by the medical ethics committee of the University Medical Center Utrecht.

Demographics and morphological parameters

A questionnaire was used to record age, gender, type of SB, lesion level, sport activities before testing, health status, use of wheelchair and type of wheelchair.

Body mass was measured using an electronic wheelchair scale (Kern MWS-300K100M, KERN & SOHN GmbH, Balingen, Germany). Height was measured using a non-stretchable tape while seated using the arm-span length (middle finger-tip to middle finger-tip) as recommended in wheelchair-dependent children, due to the presence of contractures when lying supine (14). Fat-free mass was determined with a bioelectrical impedance analysis system (BIA; The Bodystat® QuadScan 4000 System; Bodystat Ltd, Isle of Man, UK). BIA is a non-invasive simple test to distinguish lean body mass and fat by comparing conductivity and resistance in the body (15).

Exercise testing

Two graded exercise tests were used in this study; the GACT and the GWPT (see below). During these tests, physiological responses, including breath-by-breath gas analysis, were measured using a heart rate (HR) monitor (miniCardio, Hosand Technologies Srl, Verbania, Italy) and calibrated mobile gas analysis system (Cortex Metamax B3, Cortex Medical GmbH, Leipzig, Germany). The Cortex Metamax is a valid and reliable system for measuring gas-exchange parameters during exercise (16).

Graded Arm Cranking Test. During the GACT a modified McMaster All-Out Progressive Continuous Arm Cranking Protocol was performed (17) on an electro-magnetically braked arm cranking ergometer (Lode Angio, Procare BV, Groningen, The Netherlands). The participant used his/her own wheelchair in order to ensure adequate support and a stable position during the GACT. After an initial warm-up phase at 0 Watts, the resistance was increased every minute by 8 Watts. The participant was encouraged to maintain the recommended cadence of 60–80 rpm.

Graded Wheelchair Propulsion Test. The GWPT was performed on custom-made rolling bars (wheelchair ergometer) for wheelchairs (based on the Cateye ergociser 3600, Osaka, Japan). The participant was seated in his/her own wheelchair and was secured to the rolling bars. Resistance was increased by 0.1 torque increments every minute, while participants were encouraged to maintain wheelchair propulsion at the same speed throughout the test. The speed was a self-selected comfortable speed of between 60 and 120 rpm for the first few minutes of testing.

Both protocols were continued until the participant stopped due to exhaustion, despite verbal encouragement from the test leader. After a 5-min rest period, participants were tested for a maximum of 5 min at 110% of the maximum resistance they reached. This type of supra-maximal testing has been described previously in healthy adults by Rossiter et al., and is explained below under "Exercise testing parameters" (18).

For the "best test performance and feasibility study" (study 1) the children and adolescents visited the laboratory twice; once for the GACT and once for the GWPT, with 1–2 weeks between testing. For the "reliability study" (study 2) the children and adolescents visited the laboratory twice, both for the GWPT, with 1–2 weeks between testing. Conditions during testing were identical during visits 1 and 2.

Data analysis

Exercise testing parameters. Both peak and supra-maximal exercise parameters were calculated as the mean value over the highest 30 s during the exercise test. Normalized VO_2 was calculated as VO_{2peak}/kg or $VO_{2supramaximal}$/kg, and expressed as ml/kg/min.

Validity for maximal aerobic testing usually includes physiological responses and criteria for maximal exercise testing as set out by Rowland (19). These criteria are subdivided into subjective and objective criteria, where every child has to meet the first and at least 1 of the latter to confirm true maximal aerobic fitness testing. The subjective criteria include signs of intense effort (sweating; facial flushing; clear unwillingness to continue despite encouragement), whereas the objective criteria for aerobic fitness testing include an evaluation of HR_{peak} ($\geq$180 beats/min) and peak respiratory exchange ratio (RER_{peak}) ($>$0.99).

Because these objective criteria may not be applicable for wheelchair ergometry, a supra-maximal protocol, as described by Rossiter et al., was used to confirm VO_{2peak} (18). In earlier studies in our laboratory, this type of supra-maximal testing has been proven useful and feasible in children with disabilities and chronic conditions (20, 21).

Best test performance and feasibility study (study 1).

- *GACT and GWPT were compared* by calculating descriptives and differences, both at the individual level and at group level. Two-tailed *t*-tests were used to test differences between the GACT and GWPT, after testing for normal distribution and equality of means. The significance level was set at $\alpha<0.05$.
- *Maximal effort* was defined as the presence of subjective criteria for intense effort, such as sweating, facial flushing and clear unwillingness to continue despite encouragement.
- *Acceptability* was defined as the willingness to perform the test again in the future, based on experienced burden. Children and adolescents were asked which test they preferred and why.
- *Adverse events* following exercise testing were monitored by asking the children, adolescents and parents during their next visit.

Reliability study (study 2).

- *Reliability* was tested with the intra-class correlation coefficient (ICC) Shrout and Fleiss model 2.1.A (22, 23).
- *Measurement error* was analysed using the standard error of measurement$_{agreement}$ ($SEM_{agreement}$) and the smallest detectable change (SDC), calculated using the following equations.
  - $SEM_{agreement} = \sqrt{\sigma^2_m + \sigma^2_{residual}}$, where σ^2_m accounts for the systematic errors between both measurements and $\sigma^2_{residual}$ accounts for the random error (22, 23).
  - $SDC = 1.96 * \sqrt{2} * SEM_{agreement}$ (22).

RESULTS

The study population for the "best test performance and feasibility study" (study 1) comprised 13 children (9 boys, 4 girls),

Table I. *Study population*

	Study 1: Best test performance and feasibility ($n=13$)	Study 2: Reliability ($n=24$)
Level of lesion, *n*		
Thoracic	2	5
Lumbar	11	19
Anthropometrics, mean (SD)		
Age (years)	13.4 (3.5)	14.8 (3.0)
Arm span (cm)	157 (23)	160 (16)
Weight (kg)	46.2 (18.7)	54.5 (16.2)
Body mass index (kg/m^2)	17.9 (3.2)	22 (7.1)
Fat-free mass (%kg)	69.3 (7.3)	69 (14)
Hoffer ambulation level (23), *n*		
Community ambulatory	1	2
Household ambulatory	1	3
Therapeutic ambulatory	2	2
Non-ambulatory	9	17

SD: standard deviation.

Table II. *Outcome data of Graded Arm Cranking Test (GACT) and Graded Wheelchair Propulsion Test (GWPT) in young people with spina bifida (SB) who are wheelchair dependent*

	GACT Mean (SD) ($n=12$)	GWPT Mean (SD) ($n=12$)
HR_{peak}, bpm	150 (28)	165 (25)*
VO_{2peak}, ml/kg/min	19.5 (4.4)[a]	23.1 (7.3)[b]
RER_{peak}	1.19 (0.32)[a]	1.20 (0.21)[b]
Difference $VO_{2supramax}$, ml/kg/min	1.4 (4.6)[a]	0.7 (2.2)[b]
Duration of testing, min; s	7 min 11 s (4 min 22 s)	8 min 27 s (2 min 14 s)
Maximal effort	8	8
Adverse events	0	0

*$p<0.05$ for differences between Graded Arm Cranking Test (GACT) and Graded Wheelchair Propulsion Test (GWPT).
[a]$n=11$ because child did not want to wear Cortex Metamax.
[b]$n=10$ because Cortex Metamax did not function properly.
HR_{peak}: peak heart rate; bpm: beats per min; VO_{2peak}: peak oxygen uptake; RER_{peak}: peak respiratory exchange ratio; SD: standard deviation.

mean age 13.4 (age range 8–17) years. The study population for the "reliability study" (study 2) comprised 24 children (13 boys, 11 girls), mean age 14.8 (age range 8–19) years. The children in study 1 were different children from those in study 2. Children's age, height, weight, body mass index (BMI), fat-free mass, lesion level (classified according to American Spinal Injury Association (ASIA) guidelines (24)) and ambulation level according to Hoffer adapted by Schoenmakers et al. (25) are shown in Table I.

Best test performance and feasibility (study 1)

Comparison between GACT and GWPT. One child (#8) could not be tested using the GACT because his arms were too short to reach the pedals. However, all children were able to perform the GWPT. One child (#12) reported experiencing pain in his forearms in the early stage of the GWPT, and therefore this test was discontinued. Outcome data for both the GACT and the GWPT at the group level are shown in Table II and at the individual level in Table III.

At the group level peak heart rate (HR_{peak}) was significantly higher during the GWPT compared with the GACT (165 ± 25 vs 150 ± 28 beats per min (bpm), $p<0.05$). VO_{2peak} was not significantly different ($p=0.11$); however, the difference in favour of the GWPT (23.1 vs 19.5 for GACT: >15%) was clinically relevant. Other exercise testing parameters, mean duration time and maximal effort were similar.

Examining the individual results, VO_{2peak} and HR_{peak} were higher in, respectively, 6/8 and 9/11 cases in GWPT, while RER_{peak} was comparable. HR_{peak} was below 180 bpm in 10/12 cases in GACT and in 8/12 cases in GWPT. However, RER-

Table III. *Outcome data for graded exercise testing at the individual level*

	GACT					GWPT				
	VO_{2peak} ml/kg/min	$VO_{2supramax}$ ml/kg/min	HR_{peak} bpm	RER_{peak}	Time min; s	VO_{2peak} ml/kg/min	$VO_{2supramax}$ ml/kg/min	HR_{peak} bpm	RER_{peak}	Time min; s
1	27.5	28.1	198	1.18	13:30	MD[b]	MD[b]	200	MD[b]	11:00
2	18.7	23.0	172	1.27	11:00	33.7	31.7	189	1.24	11:45
3	15.3	15.3	114	1.25	4:56	13.3	13.3	157	1.59	8:20
4	20.7	10.7	163	1.19	8:13	22.0	22.7	192	1.21	11:05
5	MD[c]	MD[c]	117	MD[c]	4:22	11.7	10.7	119	0.96	6:15
6	17.0	17.7	175	1.83	13:48	24.8	19.2	162	1.43	10:00
7	26.3	25.0	140	0.77	1:12	30.7	32.0	185	1.10	5:00
8	MD[a]	MD[a]	MD[a]	MD[a]	MD[a]	28.3	30.3	172	1.06	4:27
9	21.0	23.0	142	1.04	5:30	21.0	20.7	164	1.01	7:30
10	13.3	7.3	121	0.90	3:00	13.5	14.0	131	1.04	7:10
11	21.7	22.7	132	0.96	3:26	MD[b]	MD[b]	154	MD[b]	5:16
12	28.7	27.3	180	1.04	9:24	MD[d]	MD[d]	MD[d]	MD[d]	MD[d]
13	24.0	23.3	175	1.25	10:07	25.7	25.3	165	1.01	9:30

[a]MD because arm crank ergometer was too large.
[b]MD because Cortex Metamax did not function properly.
[c]MD because child did not want to wear the Cortex Metamax.
[d]MD because child had to stop early in the test because of pain in his forearms.
GACT: Graded Arm Cranking Test; GWPT: Graded Wheelchair Propulsion Test; HR_{peak}: peak heart rate; bpm: beats per min; VO_{2peak}: peak oxygen uptake RER_{peak}: peak respiratory exchange ratio; MD: missing data.

Table IV. *Outcome aerobic fitness parameters in the Graded Wheelchair Propulsion Test (GWPT) in young people with spina bifida (SB)*

	GWPT (n=24) Mean (SD)	
	Test	Retest
HR_{peak}, bpm	185 (18)	180 (20)
VO_{2peak}, ml/kg/min[a]	23.5 (7.4)	22.8 (6.6)
RER_{peak}[a]	1.23 (0.14)	1.20 (0.15)
Duration of testing, min; s (range)	6:43 (1:36)	6:37 (1:40)
Adverse events, n	0	0

[a]n=19 due to failure of the Cortex Metamax.
HR_{peak}: peak heart rate; bpm: beats per min; VO_{2peak}: peak oxygen uptake; RER_{peak}: peak respiratory exchange ratio; SD: standard deviation.

$_{peak}$ was higher than 0.99 in 8/11 cases in GACT and in 9/10 cases in GWPT. The minimum duration time was better during GWPT compared with GACT (4 min 27 s vs 1 min 12 s, respectively). In addition, only 3 children had a duration time of less than 6 min during the GWPT compared with 6 children during the GACT. Both the GACT and the GWPT showed good results during supramaximal testing, as only very small or even negative differences were found between VO_{2peak} and $VO_{2supramaximal}$ (Table III).

Maximal effort, acceptability and adverse events. In both tests 8 children met the subjective criteria for maximal aerobic fitness testing. Most children and adolescents preferred the GWPT compared with the GACT (5/9); mostly because of familiarity with wheelchair propulsion and because of muscle fatigue in the neck, shoulders and arms during the GACT. However, 4 children did not have a preference. No adverse events occurred during testing.

Reliability (study 2)

The reliability of the GWPT was high, with excellent intra-class correlation coefficients (ICCs) for VO_{2peak} and high ICCs for HR_{peak}. The SEM was, respectively, 1.87 for VO_{2peak} and 6 for HR_{peak}. The SDC was, respectively, 5.18 for VO_{2peak} and 17 for HR_{peak}. The results are shown in Tables IV and V.

DISCUSSION

The primary aim of this pilot study was to investigate best test performance and feasibility (study 1) using GACT vs GWPT in the laboratory setting to measure VO_{2peak} in children with SB who use a wheelchair. A secondary aim was to examine the reliability of the best test (study 2). Significantly higher HR_{peak} and clinically relevant higher VO_{2peak} values were found during the GWPT compared with the GACT; other exercise parameters, maximal effort and acceptability were similar in both tests. Because of this, reliability was determined for the GWPT. The reliability was high, with excellent ICCs for VO_{2peak} and high ICCs for HR_{peak}. The SEMs were acceptable and SDCs of 5.2 for VO_{2peak} and 17 for HR_{peak} were found at the individual level.

Table V. *Outcome reliability data for the Graded Wheelchair Propulsion Test (GWPT)*

	Reliability GWPT (n=24 HR_{peak}, n=23 VO_{2peak})		
	ICC 2.1.A (95% CI)	SEMagreement	SDC
VO_{2peak}, ml/kg/min	0.93 (0.83–0.97)	1.87	5.18
HR_{peak}	0.90 (0.73–0.96)	6	17

HR_{peak}: peak heart rate; VO_{2peak}: peak oxygen uptake; SEMagreement: Standard Error of Measurement; ICC: intraclass correlation coefficient; 95% CI: 95% confidence interval; SDC: smallest detectable change.

Best test performance and feasibility (study 1)

The preference for wheelchair propulsion compared with arm cranking in this study is similar to the results of a study by Verschuren et al. (12), which reported a higher VO_{2peak} (26.0 vs 25.3 ml/kg/min) and a significantly higher HR_{peak} (172 vs 161 bpm) during a wheelchair propulsion field test compared with a maximal GACT in children with cerebral palsy. Findings for adults using a wheelchair are equivocal, with studies showing no significant differences in VO_{2peak} when comparing arm cranking with wheelchair propulsion (26–28) and results indicating higher VO_{2peak} during functional wheelchair propulsion (29, 30). Results for HR_{peak} also remain equivocal, both higher HR_{peak} during wheelchair propulsion (27, 31) and higher HR_{peak} during arm cranking (32) have been reported. The results of this study combined with the literature about children and adolescents support a change in functional propelling protocols, as suggested by Bar-Or (13).

Regarding feasibility, 1 child was unable to perform the GACT because of his limited arm span. Using the Cortex Metamax during the GACT was also complicated for older children and adolescents, due to the large dimensions of the arm crank ergometer, the flow sensor and face mask, which would probably have limited their maximum effort. Since we wanted to include children aged 6 years and over, this aspect supported our preference for the GWPT. However, 1 adolescent had to stop the GWPT prematurely, due to pain in his forearms. This individual was community ambulatory; he used his wheelchair only for long distances, which may explain the pain he experienced during the GWPT.

In this study VO_{2peak} and HR_{peak} were the main outcome parameters. Power output is also an important outcome parameter often used during aerobic fitness testing. However, it was not possible to report power output for the GWPT on the wheelchair ergometer. Measuring the resistance of the wheelchair on the ergometer is difficult, resulting in problems with measuring power output on the wheelchair ergometer. This problem could have been solved by using a wheelchair propulsion test on a treadmill, as is often used in adults with spinal cord injury who use a wheelchair (30). In our opinion this was not feasible in our population, as children and adolescents with SB are often anxious (33), which is likely to limit their maximum effort when tested on a treadmill.

Wheelchair propulsion can also be measured through field tests, such as the multistage field test and the Shuttle Ride Test (12, 34). The benefits of these field tests are the absence of expensive equipment, the specificity of the task and the possibility of testing several participants at the same time. We decided, however, that we first had to determine the best laboratory test for measuring VO_{2peak} in children and adolescents with SB who use a wheelchair, as field testing may be influenced by, for example, wheelchair skills or anaerobic performance (11). The validity and reliability of field-testing will be examined in a future study.

Validity for VO_{2peak} usually includes criteria for "maximal effort", subdivided into subjective and objective criteria (19). These criteria apply to children who are developing typically; however, there are no criteria for maximal aerobic fitness testing in children and adolescents who use a wheelchair. Also, for adults who use a wheelchair the criteria for maximal aerobic fitness testing are unclear. Therefore, Goosey-Tolfrey & Leicht (11) recommended performing a verification protocol for measuring VO_{2peak}. In this study the protocol according to Rossiter et al. (18) was used. No differences were found between VO_{2peak} and $VO_{2supramaximal}$, assuming that maximal effort was achieved in both tests. However, 2 participants (#7 and #10) achieved both relatively low HR_{peak} (140 and 121 bpm, respectively) and low RER_{peak} values (0.77 and 0.90, respectively) during GACT, assuming peripheral limitation instead of cardiovascular limitation. They did achieve higher HR_{peak} and RER_{peak} values during GWPT, again supporting our preference for using GWPT during exercise testing. When examining the criteria for maximal aerobic fitness testing for HR_{peak} and RER_{peak}, more children achieved the criterion for RER_{peak} of >0.99 compared with the criterion for HR_{peak} of >180 bpm. Future research should determine the criteria for maximal aerobic fitness testing in children and adolescents who use a wheelchair, so that these criteria can be used in both research and care.

Regarding acceptability, we asked the children and adolescents about their preference (GACT vs GWPT). Most children were able to explain why they preferred either the GACT or the GWPT. We also tried to apply the OMNI scale of perceived exertion (35) because research indicated a relationship between the rate of perceived exertion and VO_{2peak} (36). However, using the OMNI scale of perceived exertion appeared to be questionable in this population. Children and adolescents often stated they were "not tired at all", even though they were visibly flushing and sweating and both HR_{peak} and RER_{peak} were high. Most children and adolescents with SB have lower IQ scores, and they may have had difficulty interpreting the OMNI scale of perceived exertion (37, 38).

Reliability (study 2)

The mean values of VO_{2peak} in our population were 23.5 (SD 7.4) and 22.8 (SD 6.6) ml/kg/min, with a total range of 12–36.7 ml/kg/min. The SDC was 5.2 ml/kg/min, equivalent to 22% of the mean VO_{2peak}. No literature is available about intervention studies regarding VO_{2peak} in children and adolescents with SB who use a wheelchair. Differences of 4% were found after training in children and adolescents with SB who were ambulatory (39). However, a recent systematic review of exercise training programmes and wheelchair propulsion capacity in adults showed significant improvements in VO_{2peak} of 14–36% after mixed training and 10–94% after endurance training (40). The interpretation of an SDC of 5.1 ml/kg/min remains unclear in this population, in particular because of the low levels of fitness and the known inactivity of these children and adolescents (2, 3). When participating in a training programme, they may experience a steep increase in VO_{2peak} due to their low starting point. Future research may provide information about progression in VO_{2peak} after training in children and adolescents with SB and, consequently, about interpretation of the SDC.

Study limitations

This study has several limitations. The first part of this pilot study involved only 13 participants, which may have resulted in clinical, yet not statistically significant, differences. However, when combining the results with those of the reliability study, the outcomes for VO_{2peak} appear to be consistent and even higher for HR_{peak}. Therefore, and supported by the best available evidence, we consider the choice in favour of GWPT to be justified. Another possible limitation is the use of fixed protocols for both the GACT and the GWPT for all participants, as this did not take into account differences in lesion level, age, height and physical activity level. This may have influenced the duration of the tests, and therefore also VO_{2peak} and HR_{peak}. It is important to expand our knowledge and experience regarding aerobic fitness testing in children who use a wheelchair, so that guidelines for more individual protocols may be developed in the future, comparable to the Godfrey protocols for children on a cycle ergometer. Furthermore, other clinimetric properties of the GWPT remain unclear, such as the minimal clinically important difference and responsiveness; these aspects may be the focus of future research.

In conclusion, this pilot study shows higher HR_{peak} and VO_{2peak} in children and adolescents with SB who are using a wheelchair when tested during wheelchair propulsion compared with arm cranking. The GWPT showed good reliability. We recommend performing a wheelchair propulsion test for aerobic fitness testing in children and adolescents who use a wheelchair.

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