Reference Values for the Muscle Power Sprint Test in 6- to 12-Year-Old Children

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Purpose: The aims of this study were (1) to develop centile reference values for anaerobic performance of Dutch children tested using the Muscle Power Sprint Test (MPST) and (2) to examine the test-retest reliability of the MPST. **Methods:** Children who were developing typically (178 boys and 201 girls) and aged 6 to 12 years (mean = 8.9 years) were recruited. The MPST was administered to 379 children, and test-retest reliability was examined in 47 children. MPST scores were transformed into centile curves, which were created using generalized additive models for location, scale, and shape. **Results:** Height-related reference curves were created for both genders. Excellent (intraclass correlation coefficient = 0.98) test-retest reliability was demonstrated. **Conclusions:** The reference values for the MPST of children who are developing typically and aged 6 to 12 years can serve as a clinical standard in pediatric physical therapy practice. The MPST is a reliable and practical method for determining anaerobic performance in children. **(Pediatr Phys Ther 2012;24:327–332)**
Key words: child, exercise test/methods, exercise test/standards, female, male, reference standards

INTRODUCTION AND PURPOSE

Physical activity in children most often consists of brief, intermittent bouts of intense movement that are commonly accumulated in the form of unstructured activities or free play over the course of the day.[1] These short bursts of activity are also characteristic of typical movement patterns seen in many structured activities, like free "play" and sport, and likely rely primarily on anaerobic sources of energy. Whether for structured or unstructured activities, children frequently rely on the anaerobic system to support a variety of activities that require a given amount of work to be performed over a short period of time.[2] Failure of the anaerobic system is associated with a number of detrimental effects including an inability to keep up with peers during free play and sport.

Anaerobic performance increases with age, reaching a plateau around late adolescence.[3] A number of previously published studies have reported greater peak anaerobic performance in males than in females.[4] Moreover, the anaerobic performance of individuals involved in recreational sport programs is reportedly significantly better than that of those individuals who are not involved in any activities.[5] This finding suggests that sport participation might have a positive effect on anaerobic performance.

The American Physical Therapy Association Section on Pediatrics recently stated that the promotion of fitness, health, and wellness in the community is a responsibility

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all therapists should assume.[6] To assume this responsibility, however, therapists must have the proper tools to assess and monitor fitness, health, and wellness. Perhaps more importantly, they must have the ability to interpret the results of these assessments to make recommendations for improvement. In the specific context of fitness testing, interpretation is largely based on normative ranges. Alternatively, reference centile curves, which are often used as a screening tool in a clinical setting, may offer a distinct advantage over the standard reference ranges as they identify the degree to which individuals deviate from the norm for a particular outcome measure. Moreover, these curves are designed to account for changes over a broad age range; conversely, when the outcome of interest is strongly dependent on some covariate (ie, age or height), the reference range must change with the covariate. Centile curves for exercise performance in a pediatric population can be used in both a research and clinical context to compare an individual's performance with that of a larger sample of children who share similar characteristics. A score below the 25th centile may be indicative of a reduced anaerobic performance and might require further examination of the child's exercise performance, muscle power, and other possible limiting factors of performance. A score below the third centile is seen as deviant and requires further physical examination (by a physiotherapist or physician) to determine the possible cause of the deviant anaerobic performance.

A number of laboratory- and field-based tests with corresponding normative data are available for the assessment of health-related fitness (ie, flexibility, cardiorespiratory fitness, and muscular strength); however, very little information is available for more performance-related outcomes like anaerobic capacity. In fact, most assessments of anaerobic capacity in children have involved laboratory-based exercise tests that may not be readily available for use in a community setting.[7] To date, the most frequently described anaerobic test in the literature is the Wingate Anaerobic test (WAnT), which is a 30-second all-out cycling test performed on a cycle ergometer.[8,9] Although the WAnT is both reliable and valid in the pediatric population, it requires specialized and costly equipment (special cycle ergometer and software). Moreover, no reference values are available for children, making it difficult to interpret in both a clinical and community setting. Finally, the ecologic validity of the test is questionable since young children walk and run in their daily activities more often than they perform sprints on a bicycle. Taken together, these limitations suggest that an inexpensive, simple, and more physiologically relevant test of anaerobic fitness may be more appropriate for use in the community and clinical settings.

Verschuren et al[10,11] recently developed and validated the Muscle Power Sprint Test (MPST), a running-based anaerobic test, for children with cerebral palsy (CP). The test, which was found to be reliable for youth with CP between the ages of 7 and 18 years, is inexpensive, does not require any specialized equipment, and is relatively easy to administer. Much like the WAnT, however, there are currently no reference values available for healthy children. Therefore, the first aim of this study was to develop centile reference values for the MPST in children who are developing typically. The second aim was to determine the test-retest reliability of the MPST in children who are developing typically.

METHODS

Participant Recruitment

Children between the ages of 6 and 12 years were recruited from 4 local mainstream schools in the northern part of the Netherlands. Three schools were located in rural areas (first school: 55 children eligible; second school: 76; third school: 134) and 1 school in an urban area (>50 000 inhabitants; 218 children eligible). Parents and/or guardians provided written informed consent prior to their child's participation in this study. Readiness to exercise was assessed by a parental pretest questionnaire. All study procedures were approved by The Central Committee on Research Involving Human Subjects in the Netherlands.

Parental Pretest Questionnaire

The parental pretest questionnaire included questions regarding sport participation, school transport habits, and, if applicable, questions on the use of medication and the existence of medical conditions.

Sport participation was classified into 3 categories: low (only physical education [PE] sessions at school), moderate (PE and participation in organized sport up to 2 hours every week), or high (PE and more than 2 hours of organized sport participation every week).[12]

Participants

Boys and girls developing typically between the ages of 6 and 12 years were asked to participate in this study. Children were considered eligible to participate if they met the specified age range, did not use any medications that might affect exercise capacity, and were not being treated for a medical condition.

Specific exclusion criteria included impairment of motor development, use of medication affecting exercise capacity, or a diagnosis of pulmonary and/or cardiovascular disease.

Protocol

Data collection for this cross-sectional study took place over a 6-month period from September 2010 to February 2011. All participants were tested during a regular PE session in their school's gymnasium. Each child was tested individually, while the remaining participants were supervised by the teacher and asked to refrain from engaging in any strenuous activity until they completed their assessment. Height and weight were measured before performing the MPST.

Each participant was given 1 practice attempt before performing the MPST, which allowed the physical therapist to provide extra instructions when needed. All children were tested by the same pediatric physical therapist.

To examine test-retest reliability, participants from the first school (n = 51) were eligible to perform the MPST on 2 occasions, separated by 1 week. However, 4 children were unavailable to perform the second MPST, which took place in the same location and time of day as the first test.

Anthropometry

Weight and height were measured according to standard protocol, with the participant in light exercise clothing and no shoes. Weight (in kilograms) was measured using electronic weight scales (Soehnle, Nassau, Lahn, Germany) to the nearest 0.1 kg. Height (in centimeters) was measured using a wall-mounted stadiometer (Seca 206, Seca, Hamburg, Germany) to the nearest 0.5 cm. Body mass index (BMI) was calculated as weight/height^2, with weight status (underweight, overweight, obese) defined using age- and gender-specific BMI cut-points.[13,14]

Anaerobic Performance

Children performed a total of 6 timed 15-m runs at a maximum pace. Time to completion for each 15-m run was recorded to the hundredth of a second. The 15-m distance was marked by 2 taped lines on the floor, and children were instructed to run as fast as possible to cross each of these lines. A 10-second rest was provided between each of the 6 runs. Children were verbally encouraged to go as fast as possible during each run to ensure a maximal effort. For the first run the instructions given were a countdown from "ready, 3, 2, 1, go." For the other 5 sprints, a countdown from 6 to 1 and the start signal "go" proved to be sufficient. Children were retested after a 5-minute break only if they fell during 1 of the 6 runs or had false start.

The following variables were calculated for each of the 6 sprints: velocity (m/s) = distance/time, acceleration (m/s^2) = velocity/time, Force (kg/s^2) = body mass × acceleration, and power (watts) = force × velocity. Anaerobic performance was defined as peak and mean power. More specifically, peak power was the highest calculated power output among the 6 sprints. Mean power was the average power output of all 6 sprints. This parameter provides an indication of a child's ability to maintain power output over time, with greater mean power indicating better maintenance of anaerobic performance. Mean power was considered the most important parameter for the MPST.[15]

Statistical Analyses

All data analyses were performed using SPSS 17.0 (SPSS Inc, Chicago, Illinois) and R statistical program (R foundation for Statistical Computing, Vienna, Austria).[16]

Descriptive analyses were used to determine the characteristics of the study participants. A chi-square test and independent samples *t*-tests were used to test statistical significance for participant characteristics and an α level of 0.05 was adopted for this study. To analyze sports participation, a 1-way analysis of variance with a Bonferroni post hoc test was used.

Data from all participants were analyzed using the Generalized Additive Models for Location, Scale and Shape (GAMLSS; for additional information, see www.gamlss.org).[17] Age, height, gender, and their interactions were all included as possible predictors. Significant predictor variables and their effect sizes were then determined, with predictive equations constructed on the basis of these models. All data were used for model building. Height was the most discriminative variable and demonstrated the highest explained variance ($R^2 > 0.7$) with anaerobic performance. (ICC; 2-way mixed) were computed for the test-retest reliability. Intraclass correlation coefficients > 0.80 were considered acceptable.[18] Limits of agreement also were calculated according to the procedure described by Bland and Altman.[19] A Bland-Altman plot is a graphic representation of the individual subject differences between the tests plotted against the respective individual means. Using this plot rather than the conventional test-retest scatter gram, a rough indication of systematic bias and random error is provided by examining the direction and magnitude of the scatter around the zero line, respectively. Bland-Altman analysis describes the level of agreement between 2 measurements. In this analysis, the "precision" indicates how well the methods agree for an individual. By multiplying the precision by 1.96, the "limits of agreement" are calculated. This calculation represents the 95% likely range for the difference between a subject's scores on 2 tests and is an indicator of absolute reliability. The α level for statistical significance for all tests was set at <0.05.

RESULTS

Participants Characteristics

A total of 483 children were eligible to participate, 90 of whom either were excluded because of time restrictions or declined participation in the study and 14 were excluded because of preexisting medical conditions. Therefore, 379 children between the ages of 6.0 and 12.3 years (178 boys or 47%; mean age ± SD: 8.9 ± 1.7 years) were included in the development of the reference values. The characteristics of the participants are presented in Table 1. Of these, 180 children (47.5%) lived in a rural area, while 199 lived in an urban area. Participant height and BMI ranged from 112.8 to 179.1 cm (mean, 138.0 ± 12.2 cm) and 13.2 to 27.0 (mean, 17.1 ± 2.5), respectively. A total of 287 children (75.7%) were considered to be of normal weight, while 2 children (0.5%) were severely underweight, 23 were underweight (6.1%), 57 (15.1%) were overweight, and 10 (2.6%) were defined as being obese. Fifty-eight, 120, and 152 children were classified as having

TABLE 1

Characteristics of Participants

Characteristic	Boys	Girls	Total	P (♂-♀)
n	178	201	379	
Age at assessment, y				
Mean	8.8	8.9	8.9	0.56
(Range) SD	(6.0-12.3) 1.8	(6.0-12.3) 1.7	(6.0-12.3) 1.7	
Weight, kg				
Mean	32.6	33.7	33.2	0.29
(Range) SD	(18.9-80.1) 9.2	(17.8-63.7) 9.4	(17.8-80.1) 9.3	
Height, cm				
Mean	137.7	138.3	138.0	0.63
(Range) SD	(113.5-179.1) 12.2	(112.8-170.3) 12.3	(112.8-179.1) 12.2	
Body mass index				
Mean	16.9	17.3	17.1	0.14
(Range) SD	(13.5-25.5) 2.4	(13.2-27.9) 2.5	(13.2-27.9) 2.5	
Power, watt				
Mean	191.7	167.8	179.0	0.01
(Range) SD	(57.2-557.6) 91.6	(48.4-447.0) 78.6	(48.4-557.6) 85.7	
Peak power, watt				
Mean	217.4	191.6	203.7	0.007
(Range) SD	(64.4-660.8) 102.3	(58.9-523.9) 90.0	(58.9-660.8) 96.7	

low-, moderate-, and high-sport participation, respectively. Children with high-sport participation had significantly higher mean power output than children with moderate or low sport participation ($P \leq .001$). Boys had a significantly higher mean ($P = .01$) and peak ($P = .007$) power output than girls. See Table 2 for detailed information about weight classification and sports participation.

Figures 1 and 2 show the gamma distribution-generated height-related centile curves (P3, P25, P50, P75, and P97) for both sexes.

TABLE 2

Classification of Weight and Sport Intensity

Classification	Boys, n (%)	Girls, n (%)	Total, N (%)
Severe underweight	0 (0)	2 (1.0)	2 (0.5)
Underweight	12 (6.7)	11 (5.5)	23 (6.1)
Normal weight	139 (78.1)	148 (73.6)	287 (75.7)
Overweight	22 (12.4)	35 (17.4)	57 (15.1)
Obesity	5 (2.8)	5 (2.5)	10 (2.6)
Low-sport participation	21 (13.7)	37 (20.9)	58 (17.6)
Moderate-sport participation	39 (25.5)	81 (45.8)	120 (36.4)
High-sport participation	93 (60.8)	59 (33.3)	152 (46.0)

Test-Retest Reliability

Test-retest reliability was examined in 47 subjects. Peak power output demonstrated an ICC (2-way mixed model) of 0.98 (95% CI: 0.96-0.99). Similarly, the ICC for mean power output was 0.98 (95% CI: 0.95-0.99). The Bland-Altman plot (Figure 3) revealed no significant learning effect between the first and second tests. Furthermore, the Limits of Agreements ranged from −25% to 22% for mean power, indicating that a change within an individual must fall outside of this range to be considered meaningful.

DISCUSSION

The first aim of this study was to provide reference values for the MPST in 6- to 12-year-old children. The centile curves developed for mean power for both boys and girls can be used in clinical practice to assess and interpret a child's anaerobic performance.

Anaerobic performance was higher in boys than in girls. Armstrong et al[20] reported differences in mean power on the WAnT in 12-, 13- and 17-year-old children, with boys demonstrating higher peak and mean power outputs. Conversely, De Ste Croix et al[21] did not find gender differences in younger children tested with the WAnT; however,

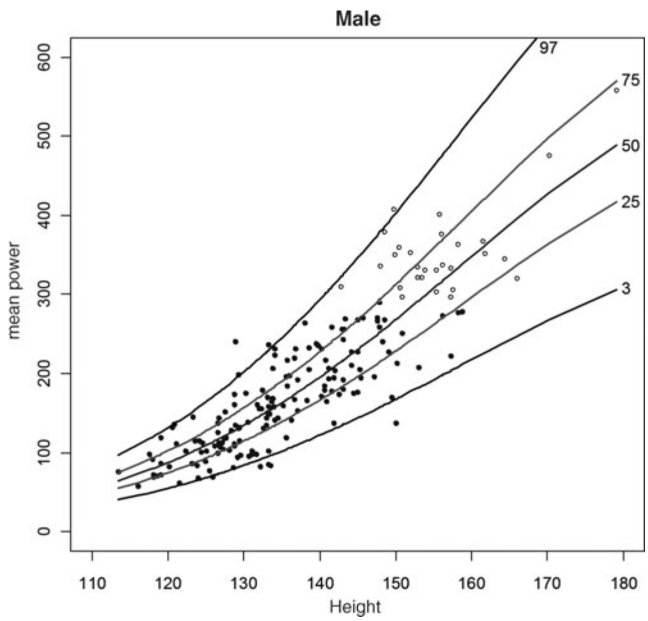

Fig 1. Mean power for boys on the Muscle Power Sprint Test.

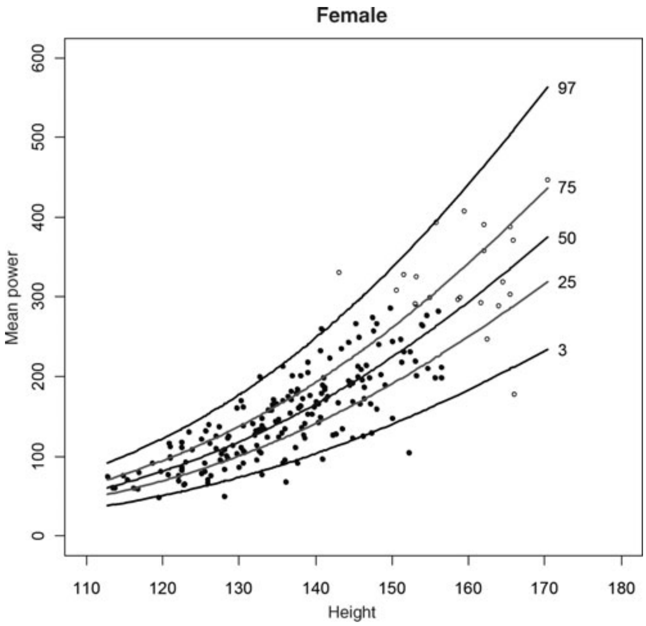

Fig 2. Mean power for girls on the Muscle Power Sprint Test.

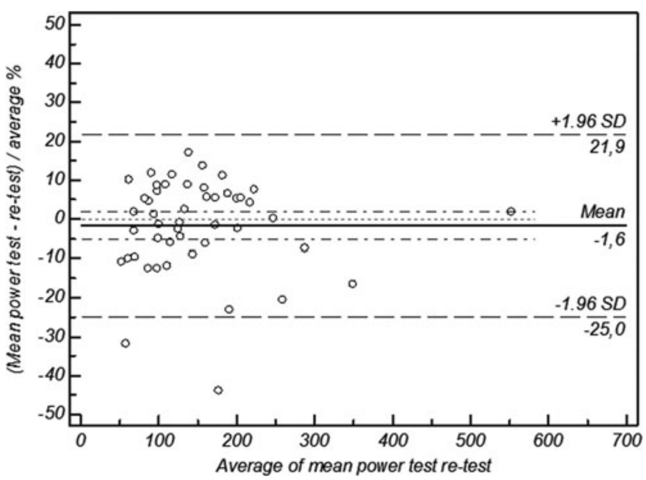

Fig 3. Bland-Altman plot (n = 47).

only 35 children were included, which might limit the statistical power. Dore et al[4] reported that boys between 14 and 20 years of age had a higher peak power on an anaerobic cycle test than girls. In the same study, no gender differences were seen in the younger age group (8-12 years). These discrepancies suggest that additional research is required to better understand potential gender differences in anaerobic performance in prepubertal children.

Our expectation was that over/underweight would have its influence on anaerobic performance; however, statistical analysis did not reveal significant differences compared with children of normal weight.

Children with higher-sport participation performed better on the MPST than those reporting low or moderate levels of participation, suggesting that sport participation may improve anaerobic performance in this age group. Ratel et al[22] found higher anaerobic performance on the WAnT in elite young athletes than in nonelite athletes and children who are developing typically. Ratel et al[23] also reported that training based on repetitive, short-term, high-intensity exercises could also improve children's anaerobic performance. More specifically, repeated runs performed at high velocities and separated by short recovery intervals were found to improve both aerobic and anaerobic performances.[23] In addition, Verschuren et al[24] reported that children with CP who were ambulatory improved their anaerobic performance, as measured using the MPST after a combined aerobic and anaerobic exercise training program. Taken together, these data indicate that children with a deficit in aerobic and anaerobic performance may benefit most from anaerobic training to improve both energy systems.

A limitation of this study is that we have defined reference values only for prepubertal children between the ages of 6 and 12 years. The literature suggests that with growth, power output will increase further as will the differences between males and females.[20] A second limitation is that the children tested were all from schools in the northern parts of the Netherlands. Although children from both rural and urban areas were tested (with no difference in power output between groups), the sample did not include children living in large cities. One might hypothesize that children from larger cities may demonstrate lower levels of anaerobic fitness when performing the MPST since they are likely to have fewer opportunities to play outside and participate in physical activity. Thus, limitations in our participant sampling may affect the generalizability of the currently reported reference values.

Clinical Implications

The current reference values for the MPST can be used to identify deficits in anaerobic performance in children with a known condition such as a pulmonary disease (asthma or cystic fibrosis) or a neurologic condition (CP). Much like the traditional clinical centiles, if a child's performance on the MPST is beneath the third centile, they are said to deviate from the norm and would benefit greatly from an exercise-based intervention. Therefore, the centile curves developed in this study are clinically relevant and strengthen the interpretation of this inexpensive, and easily administrable test to assess anaerobic performance in 6- to 12-year-old children.

Recommendations for Future Research

The MPST has been shown to be reliable, valid, and sensitive to change in children with CP.[11] Although we found good test-retest reliability in children who are developing typically, the responsiveness to change and validity of the test have yet to be examined. Moreover, this study was cross-sectional in nature; our findings may be strengthened by a similar study with a longitudinal design. Future research in children between 12 and 18 years of age may also provide additional useful information relating to the development of mean power using the MPST in relation to body height in adolescents.

CONCLUSIONS

Centile curves developed for mean power for both boys and girls can be used in clinical practice to assess and interpret a child's anaerobic performance. The MPST is a reliable and practical method for the assessment of anaerobic fitness in 6- to 12-year-old children in pediatric physical therapy practice.

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