Kotte, E.M.W., Groot, J.F. de, Bongers, B.C., Winkler, L.M.F., Takken, T. The Fitkids Treadmill Test: age- and sex-related normative values in Dutch children and adolescents. Physical Therapy: 2016, 96(11), 1764-1772

Postprint Version	1.0
Journal website	http://ptjournal.apta.org/content/early/2016/07/20/ptj.20150399.long
Pubmed link	http://www.ncbi.nlm.nih.gov/pubmed/27197825
DOI	10.2522/ptj.20150399

Fitkids Treadmill Test: Age- and Sex-Related Normative Values in Dutch Children and Adolescents

ELLES M.W. KOTTE, JANKE F. DE GROOT, BART C. BONGERS, ALEXANDER M.F. WINKLER, TIM TAKKEN

E.M.W. Kotte, MSc, Fitkids Foundation, Box 75751, 1070 AT Amsterdam, the Netherlands. Address all correspondence to Ms Kotte at: elles@fitkids.nl.
J.F. de Groot, PhD, Utrecht University of Applied Sciences, Utrecht, the Netherlands; Child Development and Exercise Center, Wilhelmina Children's Hospital, University Medical Center, Utrecht, the Netherlands; and Partner of Shared Utrecht Pediatric Exercise Research Lab, Utrecht, the Netherlands.
B.C. Bongers, PhD, Child Development and Exercise Center, Wilhelmina Children's Hospital, University Medical Center; Partner of Shared Utrecht Pediatric Exercise Research Lab; and Department of Epidemiology, School for Public Health and Primary Care, Maastricht University, Maastricht, the Netherlands.
A.M.F. Winkler, MD, Fitkids Foundation.
T. Takken, PhD, Child Development and Exercise Center, Wilhelmina Children's Hospital, University Medical Center, and Partner of Shared Utrecht Pediatric Exercise Research Lab.

ABSTRACT

BACKGROUND. Recent research has shown that the Fitkids Treadmill Test (FTT) is a valid and reproducible exercise test for the assessment of aerobic exercise capacity in healthy children and adolescents.

OBJECTIVE. To provide sex- and age-related normative values for FTT performance in healthy and typically developing children and adolescents aged 6 to 18 years. DESIGN. Cross-sectional, observational study. METHODS: Three-hundred and fifty-six healthy children and adolescents (174 boys and 182 girls; mean ± SD age: 12.9 ± 3.7 years) performed the FTT to their maximal effort to assess time to exhaustion (TTE). The Least Mean Square (LMS) method was used to generate sex- and age-related centile charts (P3, P10, P25, P50, P75, P90, and P97) for TTE attained at of the FTT.

RESULTS: In boys, the reference curve (P50) showed an almost linear increase with age in TTE from 8.8 minutes at 6 years of age to 16.1 minutes at 18 years of age. In girls, the P50 values for TTE increased from 8.8 minutes at 6 years of age to 12.5 minutes at 18 years of age, with a plateau in TTE starting at approximately 10 years of age.

LIMITATIONS: Youth from non-Caucasian origin were underrepresented in this study.

CONCLUSION: The current study describes sex- and age-related normative values for FTT performance in healthy, typically developing children and adolescents aged 6 to 18 years. Age- and sex-related normative values will increase the usefulness of the FTT in clinical practice.

INTRODUCTION

Exercise testing is being used with increasing frequency by pediatric physical therapists to assess the physical fitness of children and adolescents or to implement training programs.[1] Studies have shown that physical fitness is a powerful maker of health in youth.[2,3] With the use of cardiopulmonary exercise testing (CPET), therapists and/or exercise physiologists are able to determine peak oxygen uptake (VO_{2peak}), which is the most commonly used measure to assess aerobic fitness.[4,5] However, direct measurement of VO_{2peak} requires sophisticated respiratory gas-exchange equipment and specific training. Therefore, there is a growing interest in methods in which aerobic fitness is estimated using predicting equations from functional outcomes during exercise tests.[6]

There are several valid and reliable strategies available to estimate aerobic fitness in daily clinical practice using a cycle ergometer or treadmill.[7,8] Recently, our research group has developed a new practical treadmill protocol to assess the aerobic fitness in children and adolescents: the Fitkids Treadmill Test (FTT). This development was based on a practical request articulated by physical therapists working with the Fitkids program. The FTT has two practical advantages over other established treadmill protocols. Firstly, the protocol starts with a 0% incline, making this protocol useful in children and adolescents with limited motor performance or those using an ankle foot orthosis. Secondly, the maximal incline of the protocol is restricted to the maximal incline of standard treadmills, which is 15%, as these treadmills are most often available in outpatient physical therapy practices. A treadmill was chosen in stead of a cycle ergometer since almost all children in the Fitkids program can be appropriately tested on the treadmill, even the younger children under the age of 8 years who have relatively underdeveloped knee extensor strength and do not fit on a standard cycle ergometer because of their small leg length.

The main outcome measure of the FTT is time to exhaustion (TTE), which is defined as the point at which the participant cannot longer exercise against the speed and incline of the treadmill, despite strong verbal encouragement. In a recent study, good validity and reproducibility of the FTT in healthy children and adolescents has been reported. Aerobic fitness can be accurately predicted from FTT performance (TTE) and body mass in healthy boys and girls (R_2=0.935).[9] At this point, sex- and age-related normative values of the FTT are lacking. Normative values will increase the usefulness of the FTT in clinical practice, as a physical therapist or exercise physiologists can determine whether a child's aerobic fitness is likely to be above average, average, or below average, based on FTT performance. The aim of the current study is to provide normative values for TTE at of the FTT in healthy, typically developing children and adolescents aged 6 to 18 years.

METHODS

Participants

Healthy children and adolescents from 6 to 18 years of age were eligible to participate in this cross-sectional, observational study. The majority of the healthy children and adolescents were recruited from a primary and several secondary schools, whereas a minority of the adolescents was recruited from local recreational sports clubs. At the schools, the selection procedure was based on class lists with only name and age available. Randomly selected participants were provided with an information package. The inclusion of participants started after approval of the Central Committee on Research Involving Human Subjects in the Netherlands (CCMO). In total, 441 information packages were distributed for both the children and their parents. The modified physical activity readiness questionnaire (PAR-Q) was used to evaluate the health status of the willing participants and to assess safety for performing maximal exercise. Exclusion criteria were: a positive response to one or more questions of the modified PAR-Q, the use of medication affecting exercise capacity, cardiovascular or respiratory disease, musculoskeletal disease, metabolic disease, impaired motor development or morbid obesity (body mass index [BMI] >2.5 standard deviation [(SD]) score).

In order to construct sex- and age-related norm values, we used the Least Mean Square (LMS) method. It is not possible to perform a power calculation for setting up norm values using the LMS method. However, a minimum of 10 boys and 10 girls for each age seemed to be a feasible and sufficient number of participants to collect and construct generalizable and robust norm values. For the lowest and highest age and within the age range of 12 to 14 years, we aimed at including 15 boys and 15 girls, respectively for an optimal fit of the data at both ends of the reference curve and since we expect a major development in exercise capacity due to puberty. Informed consent was signed by both parents, as well as by children ≥12 years of age. Assent was attained from children <12 years of age.

Anthropometry

Before exercise testing, body mass, body height and sitting height were determined to the nearest 0.5 kg and 0.1 cm using an analogue scale (Medisana PSD; Medisana Benelux N.V.; Kerkrade, the Netherlands) and a stadiometer (Seca 213; Seca, Hamburg, Germany). For these measurements, participants were wearing light clothes and no shoes. BMI was derived from body mass and body height, whereas leg length was calculated by subtracting sitting height from body height. SD scores were calculated for BMI for age using Dutch reference values.[10] Subcutaneous fat of the biceps, triceps, subscapular, and supra-iliac skinfolds were measured using a Harpenden skinfold caliper (Baty International, West Sussex, United Kingdom). The sum of the average of three measures of each measuring site was used for estimating Bbody density using the equations proposed by Deurenberg et al.[11] To estimate percent body fat and subsequently calculate fat free mass (FFM), the Siri equation was used.[12] Body surface area (BSA) was calculated using the equation of Haycock et al.,[13] which has been validated in infants, children and adults[13].

Physical activity levels and sedentary time

Physical activity levels and sedentary time were assessed using the Dutch Standard Physical Activity Questionnaire for youth (Indicators Monitor Youth Health).[14] Parents were asked how many days, in a normal week, their child: (1) walks or bikes

to school, (2) plays sports at school, (3) plays sports at a sports club, (4) plays outside (outside school hours). In addition, the average duration of these activities on such a day was assessed. Sedentary screen-based behavior was assessed in a similar manner, by asking parents about their child's television watching (including videos and DVDs, YouTube) and computer playing. Children ≥12 years of age filled out the questionnaire themselves. Participants were categorized as "inactive" (<180 minutes of physical activity a week), "semi-inactive" (180 to 299 minutes of physical activity a week), "semi-active" (300 to 419 minutes of physical activity a week), or "norm active" (>420 minutes of moderate-to-vigorous intensity physical activity a week) according to the Dutch public-health guidelines for recommended levels of physical activity for children and adolescents.[15]

Fitkids Treadmill Test

Participants recruited from the primary and secondary schools were tested in a quiet room at their school and the FTT was performed on a motor driven treadmill ergometer (Lode Valiant; Lode BV, Groningen, the Netherlands). The adolescents who were recruited from sports clubs were tested at a local fitness center and a calibrated treadmill ergometer of the fitness center was used. To ensure a similar set up, the participants were mainly tested outside opening hours of the fitness center. When it was not possible to test participants outside opening hours, we have chosen to position the treadmill out of sight of other athletes during testing.

During the test, heart rate (HR) was monitored using a heart rate belt (Polar H1 transmitter; Polar, Kempele, Finland).

The FTT protocol consists of a 90-second warm-up period (3.5 $km \cdot h_{-1}$, 0% incline) followed by the initiation of the test at 3.5 $km \cdot h_{-1}$ and 1% incline for 90 seconds. After this initial period, speed is increased by 0.5 $km \cdot h_{-1}$ and incline by 2% every 90 seconds. The maximal incline is limited to 15%, but speed is increased with no limitation. The incremental increases in both speed and incline are continued until volitional exhaustion as described elsewhere.[9] The test is terminated when the participant can no longer keep up with the speed of the treadmill, despite strong verbal encouragement (standardized) (Appendix). At this point, the recovery phase of 90 seconds is initiated at a speed of 2.0 $km \cdot h_{-1}$ with a flat treadmill to ensure normal heart rate recovery. The 90-second interval of the FTT is based on the interval used in the modified Bruce and Dubowy treadmill protocols. Smaller increments will facilitate a better responsiveness of the protocol after an intervention such as an exercise training intervention. The same protocol was used for adolescents and younger children. Participants were instructed not to hold the handrails, except for touching the handrail with one or two fingers to regain balance during changes of speed and angle of inclination.

TTE (in minutes, one decimal) was defined at peak exercise. TTE is calculated as the total duration of the test minus the duration of the warm up phase. Peak HR (HR_{peak}) was defined as the highest value achieved during the last 30 seconds before test termination. The test was deemed maximal when HR_{peak} was >180 $beats \cdot min_{-1}$ and when subjective indicators of a maximal effort were obtained (e.g. sweating, unsteady walking, facial flushing and clear unwillingness to continue despite strong verbal encouragement).[16] Before and directly after the exercise test, participants were asked to rate their level of perceived exhaustion on an OMNI scale for perceived exertion (0-10). The scale starts with '0', indicating the participant is 'not tired at all', and ends with '10', meaning that the participant is 'very, very tired'. Level of

perceived exertion was determined by subtracting the pretest OMNI score from the posttest OMNI score (ΔOMNI; posttest OMNI score minus pretest OMNI score).[17]

Statistical analysis

The IBM SPSS Statistics for Windows, version 20.0 (IBM Corp, Armonk, New York, NY) was used for data analysis. The distribution of the variables was assessed using visual inspection (histogram, boxplot and normal Q-Q plot) and the Shapiro-Wilk test for normality. Differences between boys and girls in anthropometric variables and exercise variables were examined using the Mann-Whitney Tests for non-normally distributed data and the independent samples t-test for normally distributed data. Determinants of exercise capacity were identified using Spearman correlation coefficients between TTE of the FTT and anthropometric variables. We used the Least Mean Square (LMS) method to generate sex- and age-related centile charts (P3, P10, P25, P50, P75, P90, and P97) for TTE (LMS Chartmaker Pro, Medical Research Council, UK). A P-value <0.05 was considered statistically significant.

RESULTS

Participants

Of the 441 children and adolescents who received an information package of the study, 373 children and adolescents (85%) were willing to participate and 361 were tested (82%). Twelve children (3%) were not tested because of the following reasons: six had one or more positive answers on the PAR-Q, one 10-year-old girl fainted during skin fold thickness measurements and five children were excluded because of morbid obesity (BMI >2.5 SD score). The remaining 361 children performed the FTT, after which five children (1%) were excluded for analysis because of the following reasons: hyperventilation during the FTT (n=1), painful Achilles tendon (n=1), painful leg (n=1), software problems (n=1), and dizziness during the FTT (n=1). Eventually, data from 356 children and adolescents (81%), 174 boys and 182 girls, with a mean age of 12.9 ± 3.7 years were used for analysis (convenience sample). A flow chart of the inclusion procedure is presented in Figure 1. Participant characteristics are presented in Table 1.

[FIGURE 1]

[TABLE 1]

Test Performance

All participants included in the analysis performed the FTT without any adverse effects and they all met the subjective criteria of a maximal effort. All participants also met the objective criteria of a maximal effort during the FTT (HR_{peak} >180 beats·min_{-1}), except for one girl, who reached an HR_{peak} of 174 beats·min_{-1}. However, based on the subjective indicators of a maximal effort obtained by this girl we did include her data in the analysis. Figure 2 shows a scatterplot of the achieved HR_{peak} during the FTT in relation to age for the total population.

[Insert Figure 2 about here]

FTT results are presented in Table 2. Compared to girls, boys have a prolonged TTE (P<0.001) and a slightly higher HR_{peak} (P =0.011) at the FTT. The main TTE at the

FTT was 13.6 ± 3.1 minutes for boys and 11.6 ± 1.9 minutes for girls. The difference in mean HR_{peak} between boys and girls (197 versus 198 beats·min$_{-1}$) was not clinically relevant. No statistically significant differences were obtained in perceived exhaustion (ΔOMNI) between boys and girls.

[TABLE 2]

As expected, strong positive correlations were observed for boys between TTE attained at the FTT and age, body mass, body height, BSA, FFM and leg length (r values ranging from 0.679 to 0.799; with P<0.001 for all coefficients). A moderate positive correlation was found in boys between TTE at the FTT and BMI (r=0.501; P<0.001). No correlation was found between TTE at the FTT and body fat in boys. In girls, moderate positive correlations were found between TTE at the FTT and age, body mass, body height, BSA, FFM and leg length (r values ranging from 0.433 to 0.582; with P<0.001 for all coefficients). A weak positive correlation was found between TTE at the FTT and BMI (r=0.325; P<0.001). In accordance with boys, no correlation was found between TTE at the FTT and body fat in girls.
Figure 3 represents age-related normative centile charts for TTE at the FTT for boys and girls. For practical considerations we chose to use age instead of body height in the normative centile charts. Age and body height are highly correlated in children and gave similar correlations with endurance times in our study population (r=0.649; P<0.001and r=0.648; P<0.001 between age and TTE attained at the FTT and between height and TTE attained at the FTT, respectively). In boys, the normative curves (P50) showed an almost linear increase with age in TTE from 8.8 minutes at 6 years of age to 16.1 minutes at 18 years of age. In girls, the P50 values for TTE increased from 8.8 minutes at 6 years of age to 12.5 minutes at 18 years of age, with a plateau in TTE starting at approximately 10 years of age.

[TABLE 3]

[FIGURE 3]

DISCUSSION

The current study provides sex- and age-related normative values for FTT performance (TTE) in healthy, typically developing children and adolescents between 6 and 18 years of age. As the FTT starts with a flat treadmill, has small incremental steps, and a lower maximal incline than most of the established maximal treadmill protocols, the FTT is useful in children and adolescents with limited motor performance, balance problems or those using an ankle foot orthosis as well.
Over the past three decades, normative values have been reported for standard maximal treadmill exercise protocols like the Bruce or the Balke protocol, as well as for several stepwise protocols with increments in speed, incline or both.[18] Various shortcomings can be noted for these studies, which hinder implementation in clinical practice. Many studies assessed outcome measures that require sophisticated respiratory gas-exchange equipment.[19-28] Others used a treadmill protocol that requires an advanced treadmill with high slope.[21,23,26,27,29-32] Besides, several studies have included a limited sample of participants in terms of sample size,[21,24,26] age range,[19,22] environmental conditions (altitude)[28] or different ethnic background (non-

Caucasians).[21,25] Some studies assessed outcome measures using individualized treadmill protocols. For instance the protocol used in the study of Al-Hazzaa et al.,[25] in which the speed of the treadmill depended on a child's age and ability to run comfortably on a treadmill. Outcome measures obtained in studies using individually-tailored treadmill protocols, however, cannot be compared with other studies. A recent extensive overview of existing pediatric norms can be found elsewhere.[18]

To our knowledge, there are no studies published that tackled most of these shortcomings and published pediatric normative values on exercise parameters that do not require respiratory gas analysis, using a treadmill protocol that can be applied when restricted to a standard treadmill with maximal incline of 15%. Although Dubowy et al.,[29] van der Cammen-van Zijp et al.[30,31] and Binkhorst et al.[32] used protocols with high incline (>15%), these studies are of interest for our setting in the Netherlands, as these studies established pediatric normative values on exercise parameters (maximal endurance times) that do not require respiratory gas analysis using a Caucasian study population. Dubowy et al.[29] used a stepwise protocol with incremental speed and incline every 90 seconds. They included 1195 participants aged 3.0 to 75.0 years old.[29] Van der Cammen-van Zijp et al.[30,31] and Binkhorst et al.[32] used the Bruce protocol. Binkhorst et al.[32] included 279 healthy Dutch children (6 to 18 years of age) and van der Cammen-van Zijp at al.[30] included 267 healthy Dutch children (6 to 13 years of age). In a separate study, van der Cammen-van Zijp et al.[31] also described normative values for maximal endurance times using the Bruce treadmill protocol for 4- and 5-year-old children in which 80 healthy children were included. In the current study, 356 children between the ages of 6 to 18 years were included. Although Dubowy et al.[29] included a large sample, the exact number of children and adolescents included was not mentioned. With respect to the studies of van der Cammen-van Zijp et al.[30,31], normative values were established for a slightly broader pediatric age range in the current study (6-18 years compared to 4-13 years in the studies of van der Cammen-van Zijp et al.).

When comparing the normative curves for TTE established in the current study with those provided by Dubowy et al.[29] it can be concluded that similar patterns were obtained. For boys, the normative curve for TTE of the FTT showed an almost linear increase with age. In girls, the increase in TTE values attained at the FTT started to level off at the age of approximately 10 years of age. The endurance time achieved by males in the study of Dubowy et al.[29] increased until the age of 19 years, whereas in females it decreased continuously from puberty. Van der Cammen-van Zijp et al.[30] and Binkhorst et al.[32] also obtained similar patterns.

Study limitations

A limitation of the current study is that youth from non-Caucasian origin were underrepresented.

Future research

Further study of the FTT is warranted and should investigate the clinimetric properties, as well as the responsiveness of the FTT in clinical populations, such as in children with cardiovascular disease, pulmonary disease, limited motor performance, or balance problems.

CONCLUSION

The current study provides sex- and age-related normative values for FTT performance in healthy, typically developing children and adolescents between 6 and 18 years of age. In boys, the normative curves showed an almost linear increase with age in TTE. In girls, values started to level off at the age of approximately 10 years.

Acknowledgments

Ms Kotte, Dr de Groot, Dr Winkler, and Dr Takken provided concept/idea/research design. Ms Kotte, Dr de Groot, Dr Bongers, and Dr Takken provided writing and data analysis. Ms Kotte and Dr Bongers provided data collection and participants. Ms Kotte, Dr Bongers, Dr Winkler, and Dr Takken provided project management. Ms Kotte and Dr Winkler provided fund procurement. Ms Kotte and Dr Takken provided facilities/equipment. Dr Takken provided institutional liaisons and administrative support. Dr de Groot and Dr Winkler provided consultation (including review of manuscript before submission).

This study was financed by the Johan Cruyff Foundation, the Rabobank Foundation, and SIA RAAK (PRO-4-03). The authors are very grateful to Lode BV, Groningen, the Netherlands, and ProCare BV, Groningen, the Netherlands, for the technical support during the study. The authors thank the participating schools: Basisschool de Wiekslag, Tubbergen, the Netherlands, and R.K. Scholengemeenschap Canisius, Almelo and Bonhoeffer College, Castricum, the Netherlands. They also thank the Child Development & Exercise Center, University Medical Center Utrecht, Utrecht, the Netherlands, and the participating sports clubs. The authors thank the students for their assistance during data collection. Finally, the authors are especially grateful to all of the participants.

REFERENCES

1 Rowland JL, Fragala-Pinkham M, Miles C, O'Neil ME. Scope of Pediatric Physical Therapy Practice in Health Promotion and Fitness for Youth with Disabilities. Pediatr Phys Ther. 2015;27:2-15.
2 Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes (Lond). 2008;32:1-11.
3 Ruiz JR, Castro-Pinero J, Artero EG, et al. Predictive validity of health-related fitness in youth: a systematic review. Br J Sports Med. 2009;43:909-923.
4 Shephard RJ, Allen C, Benade AJ, et al. The maximum oxygen intake: an international reference standard of cardiorespiratory fitness. Bull World Health Organ. 1968;38:757-764.
5 Vanhees L, Lefevre J, Philippaerts R, et al. How to assess physical activity; how to assess physical fitness? Eur J Cardiovasc Prev Rehabil. 2005;12:102-114.
6 Bongers BC. Pediatric Exercise Testing: In Health and Disease [thesis]. Maastricht, the Netherlands: Universitaire Pers Maastricht; 2013: 1-82.
7 Bongers BC, de Vries SI, Helders PJ, Takken T. The steep ramp test in healthy children and adolescents: reliability and validity. Med Sci Sports Exerc .2013;45:366-371.
8 Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J. 1973;85:546-562.
9 Kotte EM, de Groot JF, Bongers BC, et al. Validity and reproducibility of a new treadmill protocol: the Fitkids Treadmill Test. Med Sci Sports Exerc. 2015;47:2241-2247.
10 Schönbeck Y, Talma H, van Dommelen P, et al. Increase in prevalence of overweight in Dutch children and adolescents: a comparison of nationwide growth studies in 1980, 1997 and 2009. PLoS One. 2011;6:e27608.
11 Deurenberg P, van der Kooy K, Hautvast JG. The assessment of the body composition in the elderly by densitometry, anthropometry and bioelectrical impedance. Basic Life Sci. 1990;55:391-393.
12 Weststrate JA, Deurenberg P. Body composition in children: proposal for a method for calculating body fat percentage from total body density or skinfold-thickness

measurements [erratum in: Am J Clin Nutr. 1991;54:428; Am J Clin Nutr. 1991;54:590]. Am J Clin Nutr. 1989;50:1104-1115.
13 Haycock GB, Schwartz GJ, Wisotsky DH. Geometric method for measuring body surface area: a height- weight formula validated in infants, children, and adults. J Pediatr. 1978;93:62-66.
14 Indicators Monitor Youth Health. Standard Questionnaire for Physical Activity: Indicatoren voor de Monitor Jeugdgezondheid. Standaardvraagstelling Bewegen. www.monitorgezondheid.nl/jeugdindicatoren.nl (in Dutch).
15 De Vries SI, Bakker I, van Overbeek K, et al. Kinderen in prioriteitswijken: lichamelijke (in)activiteit en overgewicht. Leiden, the Netherlands: TNO Kwaliteit van Leven; 2005.
16 Bongers BC, Hulzebos HJ, van Brussel M, Takken T. Pediatric Norms for Cardiopulmonary Exercise Testing: In Relation to Sex and Age. 2nd ed. Hertogenbosch, the Netherlands: Uitgeverij BOXpress; 2014.
17 Robertson RJ, Goss FL, Andreacci JL, et al. Validation of the children's OMNI RPE scale for stepping exercise. Med Sci Sports Exerc. 2005;37:290-298.
18 Blais S, Berbari J, Counil FP, Dallaire F. A systematic review of reference values in pediatric cardiopulmonary exercise testing. Pediatr Cardiol. 2015;36:1553-1564.
19 Armstrong N, Williams J, Balding J, et al. The peak oxygen uptake of British children with reference to age, sex and sexual maturity. Eur J Appl Physiol Occup Physiol. 1991;62:369-375.
20 Reybrouck T, Weymans M, Stijns H, et al. Ventilatory anaerobic threshold in healthy children: age and sex differences. Eur J Appl Physiol Occup Physiol. 1985;54:278-284.
21 Nagano Y, Baba R, Kuraishi K, et al. Ventilatory control during exercise in normal children. Pediatr Res. 1998;43:704-707.
22 Marinov B, Kostianev S, and Turnovska T. Ventilatory response to exercise and rating of perceived exertion in two pediatric age groups. Acta Physiol Pharmacol Bulg. 2000;25:93-98.
23 Marinov B, Mandadzhieva S, and Kostianev S. Oxygen-uptake efficiency slope in healthy 7- to 18- year-old children. Pediatr Exerc Sci. 2007;19:159-170.
24 Loftin M, Sothern M, Trosclair L, et al. Scaling VO2 peak in obese and non-obese girls. Obes Res. 2001;9:290-296.
25 Al-Hazzaa HM. Development of maximal cardiorespiratory function in Saudi boys: a cross- sectional analysis. Saudi Med J. 2001;22:875-881.
26 Gursel Y, Sonel B, Gok H, Yalcin P. The peak oxygen uptake of healthy Turkish children with reference to age and sex: a pilot study. Turk J Pediatr. 2004;46:38-43.
27 Geithner CA, Thomis MA, Vanden Eynde B, et al. Growth in peak aerobic power during adolescence. Med Sci Sports Exerc. 2004;36(9):1616-1624
28 Ilarraza-Lomelí H, Castañeda-López J, Myers J, et al. Cardiopulmonary exercise testing in healthy children and adolescents at moderately high altitude. Arch Cardiol Mex. 2013;83:176-182.
29Dubowy KO, Baden W, Bernitzki S, Peters B. A practical and transferable new protocol for treadmill testing of children and adults. Cardiol Young. 2008;18:615-623.
30 Van der Cammen-van Zijp MH, van den Berg-Emons RJ, Willemsen SP, et al. Exercise capacity in Dutch children new reference values for the Bruce treadmill protocol. Scand J Med Sci Sports. 2010;20:e130-e136.
31 Van der Cammen-van Zijp MH, IJsselstijn H, Takken T, et al. Exercise testing of pre-school children using the Bruce treadmill protocol: new reference values. Eur J Appl Physiol. 2010;108:393-399.
32 Binkhorst RA, van 't Hof MA, Saris WH. Maximale inspanning door kinderen; referentiewaarden voor 6-18 jarige meisjes en jongens. Brochure Nederlandse Hartstichting. 1992.

TABLES AND FIGURES

Table 1. Participant characteristics

		Boys			Girls			
		n	*Mean ± SD*	*Range*	*n*	*Mean ± SD*	*Range*	*P-value*
Age (years)	Total	174	13.0 ± 3.7	[6.3 - 18.8]	182	12.8 ± 3.7	[6.1 - 18.9]	0.700
	6-12 years	81	9.6 ± 2.2	[6.3 - 12.9]	88	9.6 ± 2.2	[6.1 -13.0]	0.900
	13-18 years	93	15.9 ± 1.7	[13.1 - 18.8]	94	15.8 ± 1.6	[13.3 - 18.9]	0.726
Body mass (kg)	Total	174	48.5 ± 17.8	[18.5 - 92.0]	182	46.6 ± 16.3	[18.0 - 83.0]	0.347
	6-12 years	81	33.4 ± 9.4	[18.5 - 58.5]	88	33.8 ± 11.4	[18.0 - 66.0]	0.742
	13-18 years	93	61.7 ± 11.8	[32.5 - 92.0]	94	58.7 ± 9.6	[40.0 - 83.0]	0.042*
Body height (m)	Total	174	1.60 ± 0.21	[1.13 - 1.97]	182	1.56 ± 0.18	[1.17 - 1.86]	0.016*
	6-12 years	81	1.42 ± 0.14	[1.13 - 1.71]	88	1.41 ± 0.14	[1.17 - 1.70]	0.769
	13-18 years	93	1.76 ± 0.10	[1.44 - 1.97]	94	1.69 ± 0.07	[1.53 - 1.86]	<0.001**
BMI ($kg \cdot m^{-2}$)	Total	174	18.2 ± 2.8	[12.6 - 25.8]	182	18.5 ± 3.4	[10.7 - 28.5]	0.426
	6-12 years	81	16.3 ± 2.1	[12.6 - 22.9]	88	16.4 ± 2.6	[10.7 - 25.7]	0.995
	13-18 years	93	19.8 ± 2.3	[15.1 - 25.8]	94	20.5 ± 2.7	[16.2 - 28.5]	0.138
BSA (m^2)	Total	174	1.45 ± 0.36	[0.77 - 2.23]	182	1.40 ± 0.33	[0.76 - 2.06]	0.218
	6-12 years	81	1.13 ± 0.21	[0.77 - 1.66]	88	1.14 ± 0.25	[0.76 - 1.73]	0.753
	13-18 years	93	1.72 ± 0.21	[1.13 - 2.23]	94	1.65 ± 0.16	[1.31 - 2.06]	0.007*
FFM (kg)	Total	174	40.3 ± 14.3	[16.1 - 74.0]	180	36.3 ± 11.6	[15.1 - 59.5]	0.011*
	6-12 years	81	27.9 ± 7.1	[16.1 - 46.6]	87	26.8 ± 8.0	[15.1 - 48.2]	0.188
	13-18 years	93	51.2 ± 9.2	[27.7 - 74.0]	93	45.2 ± 6.1	[32.1 - 59.5]	<0.001**
Body fat (%)	Total	174	16.4 ± 3.5	[7.4 - 27.2]	180	20.7 ± 4.0	[11.9 - 30.4]	<0.001**
	6-12 years	81	15.8 ± 3.7	[7.4 - 27.2]	87	18.9 ± 3.8	[11.9 - 30.4]	<0.001**
	13-18 years	93	16.9 ± 3.2	[10.8 - 26.1]	93	22.4 ± 3.5	[15.5 - 30.4]	<0.001**
BMI for age[a]	Total	174	0.0 ± 1.0	[-3.2 - 2.3]	182	0.0 ± 1.1	[-5.1 - 2.5]	0.936
	6-12 years	81	-0.1 ± 1.2	[-3.2 - 2.3]	88	-0.2 ± 1.2	[-5.1 - 2.5]	0.478
	13-18 years	93	0.1 ± 0.9	[-2.0 - 2.2]	94	0.2 ± 0.9	[-1.7 - 2.5]	0.362
Inactive n (%)[b]	Total	156	0 (0)		170	2 (1)		
	6-12 years	80	0 (0)		86	1 (1)		
	13-18 years	76	0 (0)		84	1 (1)		
Semi-inactive n (%)[b]	Total	156	5 (3)		170	12 (7)		
	6-12 years	80	3 (4)		86	4 (5)		
	13-18 years	76	2 (3)		84	8 (10)		
Semi-active n (%)[b]	Total	156	16 (10)		170	25 (15)		
	6-12 years	80	7 (9)		86	14 (16)		
	13-18 years	76	9 (12)		84	11 (13)		
Norm active n (%)[b]	Total	156	135 (87)		170	131 (77)		

	6-12 years	80	70 (88)	86	67 (78)	
	13-18 years	76	65 (86)	84	64 (76)	
>2h a day ST n (%)	Total	166	73 (44)	177	64 (36)	
	6-12 years	81	31 (38)	86	27 (31)	
	13-18 years	85	42 (49)	91	37 (41)	

Data are presented as mean ± SD, [range].

Abbreviations: SD=standard deviation; BMI=body mass index, BSA=body surface area; FFM=fat free mass; ST=Sedentary time.

[a]: standard deviation score.

[b]: based on Dutch public-health guidelines for recommended levels of physical activity for children and adolescents (5-18 years)[15].

* P<0.05; ** P<0.001.

Table 2. FTT results

	Boys (n=174)		Girls (n=182)		P-value
TTE (min)	13.6 ± 3.1	[7.5 - 24.5]	11.6 ± 1.9	[7.5 - 18.3]	<0.001**
HR_{peak} (beats·min^{-1})	197 ± 7	[180 - 214]	198 ± 7	[174 - 220]	0.011*
ΔOMNI [a]	9.2 ± 1.2	[3.0 - 10.0]	8.9 ± 1.4	[2.0 - 10.0]	0.061

Abbreviations: FTT=Fitkids Treadmill Test; TTE= Time to exhaustion; HR_{peak}= Peak heart rate

[a]: ΔOMNI is based on n=173 boys.

* P<0.05. ** P<0.001.

Table 3. Spearman correlation between TTE on the FTT and anthropometric variables

	Boys (n=174)		Girls (n=182)	
Age (years)	r=0.779	P<0.001**	r=0.582	P<0.001**
Body mass (kg)	r=0.720	P<0.001**	r=0.515	P<0.001**
Body height (m)	r=0.679	P<0.001**	r=0.433	P<0.001**
BMI	r=0.501	P<0.001**	r=0.325	P<0.001**
BSA	r=0.693	P<0.001**	r=0.446	P<0.001**
FFM (kg) [a]	r=0.720	P<0.001**	r=0.494	P<0.001**
Body fat (%)[a]	r=-0.046	NS	r=0.111	NS
Leg length	r=0.688	P<0.001**	r=0.522	P<0.001**

Abbreviations: BMI=body mass index, BSA=body surface area; FFM=fat free mass

[a]: Body fat and FFM were not determined in two girls, so body fat and FFM are based on n=180 girls.

** P<0.001.

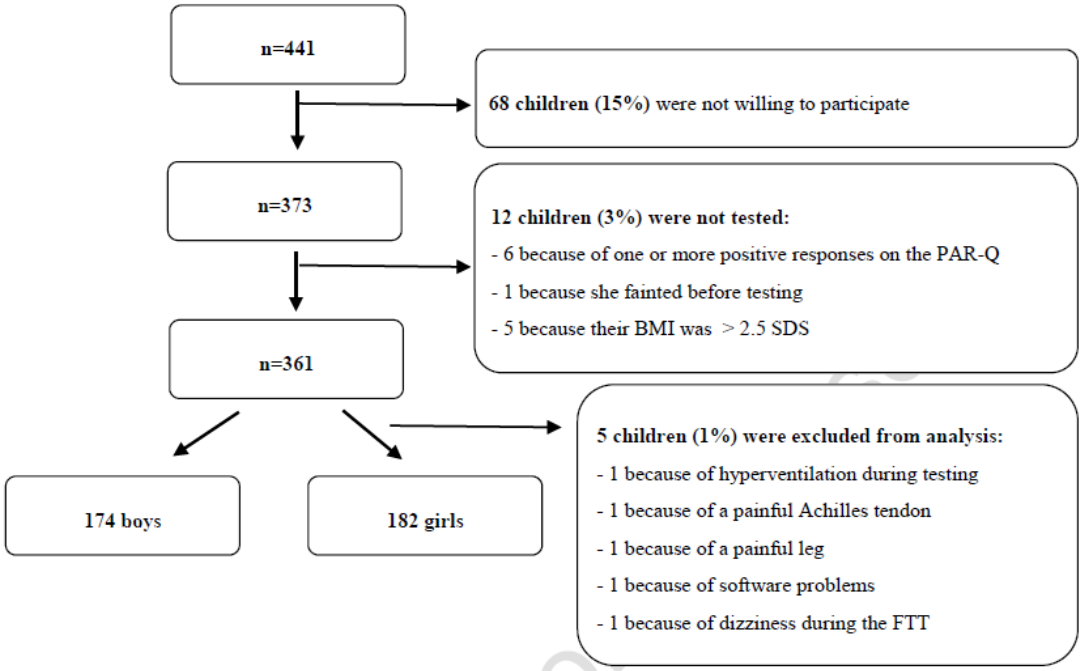


Figure 1. Flow chart of the inclusion procedure.

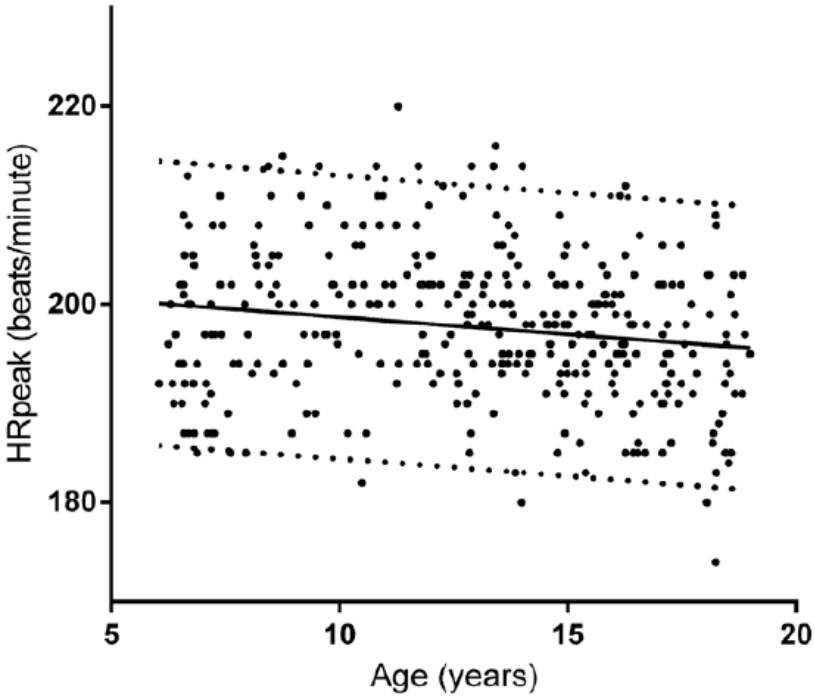
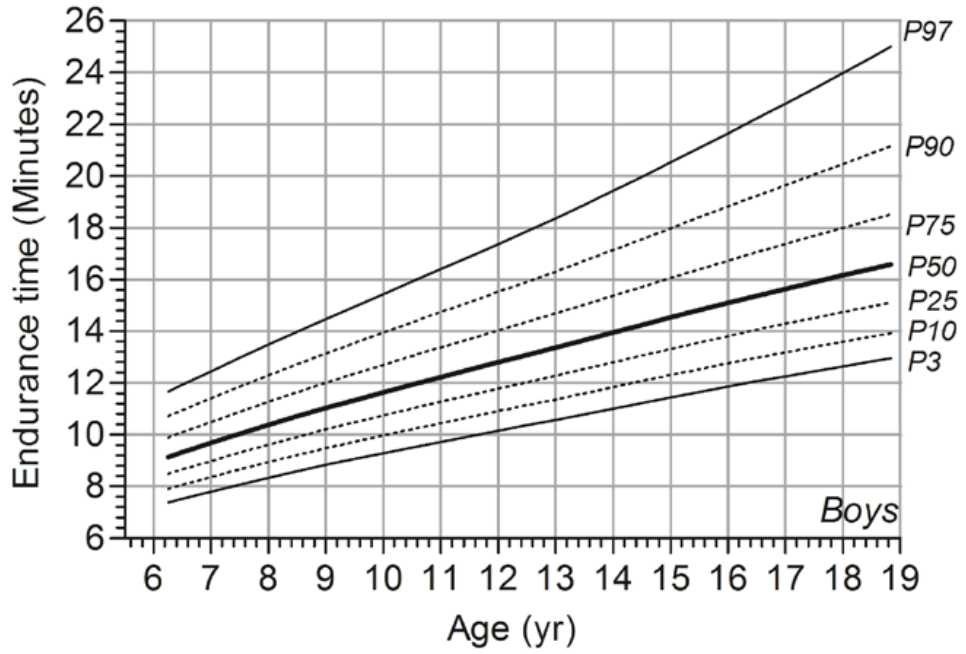


Figure 2. Age in relation to HR_{peak} attained at the FTT for the total study population.

Abbreviations: FTT=Fitkids Treadmill Test; HR_{peak}= Peak heart rate



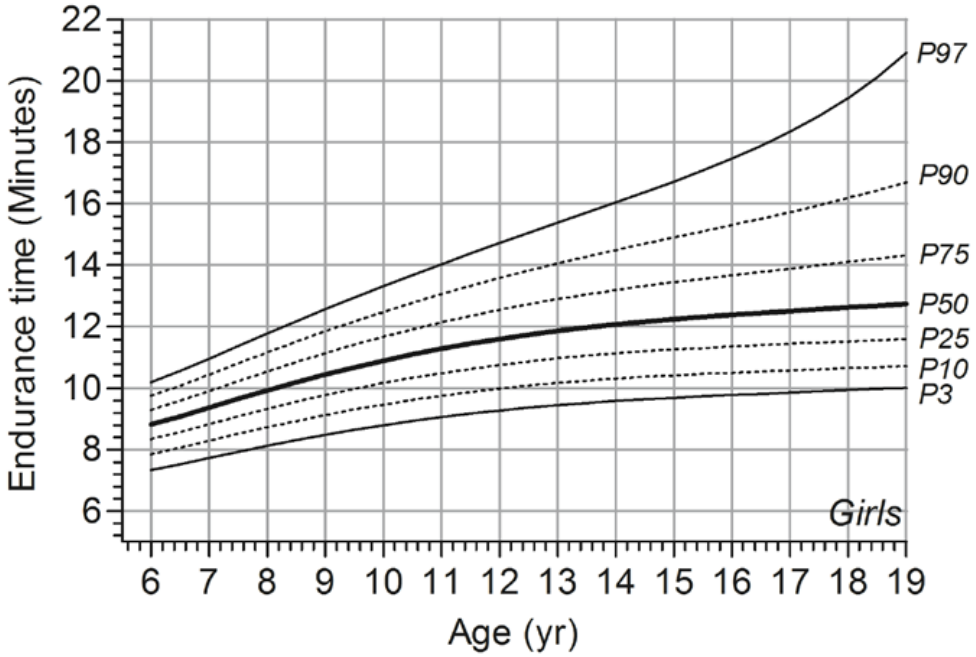


Figure 3.
Age-related centile charts for TTE at the FTT for boys and girls separately. The following equations can be used to predict the 50th centile (P50) for TTE at the FTT (minutes) from age (years).
Boys: P50 TTE = (0.5870 x age) + 5.688 (R_2=0.99)

Girls: P50 TTE = (0.8817 x age) + (-0.02359 x age^2) + 4.384 (R_2=0.99)
Abbreviations: FTT=Fitkids Treadmill Test; TTE= Time to exhaustion