Six-Minute Walk Distance in Overweight Children and Adolescents: Effects of a Weight-Reducing Program

Ralf Geiger, MD, PhD, Julia Willeit, MD, Meike Rummel, MSc, Wolfgang Högler, MD, PhD, Kurt Stübing, MD, Alexander Strasak, MD, PhD, Harald Geiger, MD, Joerg I. Stein, MD, PhD, and Markus Rauchenzauner, MD, PhD

Objective To assess the significance of consecutive six-minute walk tests (6MWTs) during a weight reduction program.

Study design Overweight children and adolescents (n = 113; mean ± standard deviation age, 12.9 ± 2.0 years; 64 girls) performed a standardized 6MWT at the beginning and end of an in-patient weight reduction program consisting of exercise, diet, and educational and psychological support. Their 6-minute walk distance (6MWD) was compared with age- and sex-matched normal-weight children (n = 353).

Results Preintervention 6MWD averaged 93% of control subjects (631 ± 88 m versus 675 ± 70 m, $P < .001$) and increased significantly to 667 ± 90 m ($P < .001$) after 27 ± 7 days of intervention (99% of control subjects; $P = .260$). Participants reduced their body weight from 80.9 ± 19.8 kg to 75.6 ± 19.0 kg, body mass index (BMI) percentile from 98.2 ± 2.1% to 96.8 ± 3.8%, and BMI–standard deviation score from 2.37 ± 0.6 to 2.13 ± 0.6 ($P < .001$ for each variable). BMI–standard deviation score, height, and the change in heart rate during the 6MWT were significant independent predictors of the 6MWD at preintervention and at post intervention time points ($P < .001$ each).

Conclusions The 6MWD increases during a weight reduction program, indicating improvement of physical fitness and decreased metabolic demand during daily activities in overweight children. The 6MWT represents a practical and reliable assessment tool for exercise performance in overweight children and adolescents. *(J Pediatr 2011;158:447-51)*.

Overweight during childhood is a major risk factor for metabolic and endocrine dysfunctions such as insulin resistance, fatty liver disease, type 2 diabetes mellitus, and cardiovascular disease in young adult life.[1-5] Mounting evidence demonstrates that regular physical activity is associated with significant reductions in abdominal obesity (visceral fat mass) and hazardous health effects.[6,7] As a consequence, weight reduction programs for overweight children are increasingly used to reverse overweight-related health risks. Assessing effectiveness of such programs on motor abilities relies on meaningful anthropometric and physical performance indicators. Motor abilities of overweight children are usually below average and can improve during the intervention.[8] Nevertheless, there is still a lack of standardized protocols, assessment tools, and reference data to measure exercise performance and effectiveness.

The 6-minute walk test (6MWT) is a valuable and practical tool to measure exercise performance on a submaximum level in children,[9] reflecting activities of daily living better than any other functional walk test.[10] Recently published reference values for the 6-minute walk distance (6MWD) have facilitated the use of the 6MWT in the pediatric population,[11,12] with good reproducibility and validity.[13-15] To date, only a few studies have used the 6MWT in overweight children and adolescents. Lower 6MWDs were reported in overweight compared with normal-weight children.[16,17] Unfortunately, prospective studies on consecutive 6MWTs in overweight children are sparse, limiting comparability of treatment approaches or components.[18] The aims of this study were to evaluate the significance of the 6MWT as an assessment tool in a weight reduction program and to identify possible predictors of the 6MWD in overweight children and adolescents.

BIA	Bioelectrical impedance analysis
BFM	Body fat mass
BFM%	Percentage body fat mass
BMI	Body mass index
FFM	Fat-free mass
HR	Heart rate
SDS	Standard deviation score
TBW	Total body water
6MWT	Six-minute walk test
6MWD	Six-minute walk distance

From the Department of Pediatrics, Clinical Divisions of Cardiology, Pulmology, Allergology, and Cystic Fibrosis (R.G., J.W., J.S.) and Neonatology, Neurology, and Metabolic Diseases (M.R.), Innsbruck Medical University, Innsbruck, Austria; Fachklinik Prinzregent Luitpold (M.R., K.S.), Scheidegg, Allgäu, Germany; Kinderarzt Praxis (H.G.), Dornbirn, Austria; the Department of Medical Statistics, Informatics, and Health Economics (A.S.), Innsbruck Medical University, Innsbruck, Austria; and the Department of Endocrinology and Diabetes (W.H.), Birmingham Children's Hospital, Birmingham, United Kingdom

The authors declare no conflicts of interest.

 10.1016/j.jpeds.2010.08.020

Methods

The in-patient weight reduction program was carried out at the Fachklinik Prinzregent Luitpold in Scheidegg/Allgäu, Germany, during summer holidays from July to September 2007. The study group comprised overweight and obese children and adolescents who participated in the program, following referral by either general practitioners or pediatricians. Inclusion criterion was "a body mass index (BMI) above the 85th percentile based on BMI curves for German children." According to the study protocol, only participants who stayed at the clinic for at least 3 weeks were included in the data analysis. Informed consent to participate in the study was obtained at the time of admission and was not a prerequisite to join the program. All children and adolescents had a physical health check on admission and were excluded if they had any physical condition other than overweight. Participants followed an intervention program consisting of regular physical exercise, moderate dietary restriction (1400 to 1600 kcal/d), comprehensive dietary and behavioral education, and psychological support. The contents of the program follow recommendations of the "Konsensusgruppe Adipositasschulung im Kindes und Jugendalter (KgAS)" (http://www.adipositas-schulung.de).

Preintervention and postintervention measures included height, weight, bioelectric impedance analysis (BIA), and 6MWT. Height and weight were measured in light clothes using an electronic scale and a wall-mounted stadiometer, respectively. BMI was calculated as kg/m^2, and individual BMI data were converted to standard deviation scores (SDS). The calculation of SDS values was based on national reference data for German children.[19]

Body fat mass (BFM) and fat-free mass (FFM) were estimated by BIA (Nutriguard S, Data Input, Darmstadt, Germany) at a frequency of 50 kHz. Total body water (TBW) was calculated from total body resistance, height, weight, and age. Fat mass was derived using the software for children available on the analyzer.

Standardized 6MWTs were performed in the individual child by using a measuring wheel as an incentive device.[12,20] Blood pressure, transcutaneous oxygen saturation, and heart rate were recorded before and immediately after the 6MWT by using the Bedside Monitor BMS-2301 (Nihon Kohden, Rosbach, Germany). Resting heart rate was obtained at least 5 minutes before commencing the walk. The change in heart rate during the 6-minute walk (ΔHR) was calculated by subtracting the resting heart rate from the heart rate immediately after the test. The 6MWDs and morphometric data were compared with those of 353 age- and sex-matched normal-weight children (BMI between the 5th and 85th percentiles) published, in part, previously.[12] The study was approved by the institutional ethic committee and local authorities.

Continuous data are presented as mean (SD). Normal distribution of data was assessed using Kolmogorov-Smirnov test. Children were grouped into overweight children and control subjects. Univariate comparisons between overweight children at start and at end of the weight reduction program were performed using paired-samples *t* tests. Cross-sectional comparisons between groups (overweight versus control subjects) were performed using independent-sample *t* tests. To identify predictors for the 6MWD, multiple regression analysis was performed using a stepwise forward variable selection procedure with a probability of F to enter $\leq$.05 and a probability of F to remove $\geq$.10. All analyses were performed two-tailed with *P* values $\leq$.05 indicating statistical significance. Statistical analyses were performed using the Statistical Package for Social Sciences for Windows (SPSS Inc, Chicago, Illinois, version 15.0).

Results

Overweight children and adolescents (n = 132) were eligible, and none of the participants or parents refused to perform the 6MWT. Nineteen participants were lost to follow-up because they were either sick or not available at the day of the second test. Therefore, 113 overweight children and adolescents (49 boys; age, 12.6 ± 2.1 years) and 64 girls (age, 13.1 ± 1.9 years) with a mean age of 12.9 ± 2.0 years (range, 8.0 to 17.0 years) remained for data analysis. Demographic and morphometric data of overweight and control groups are depicted in **Table I**. By design, subjects of the two groups differed in respect to their weight, BMI, BMI percentiles, and BMI-SDS. After a mean of 27 ± 7 days, overweight participants achieved reductions in body weight from 80.0 ± 19.8 kg to 75.6 ± 18.9 kg, $P < .001$, in percentage body fat mass (BFM %) from 35.9% ± 6.8% to 33.4% ± 7.1%, $P < .001$, BMI percentile 98.2% ± 2.1% to 96.8% ± 3.8%, $P \leq .001$), and BMI-SDS (2.37 ± 0.6 to 2.13 ± 0.6, $P \leq .001$).

6MWD in the overweight children and adolescents increased from 631 ± 88 m at baseline to 667 ± 90 m after intervention, $P < .001$. At the start of the program, 6MWD averaged 93% of the mean for age-matched normal weight children (631 ± 88 m versus 675 ± 70 m, $P < .001$) but was no more different thereafter (667 ± 90 m versus 675 ± 70 m, $P = .260$; 99%). Similar to normal-weight children, 6MWD was shorter in overweight girls than in overweight boys (both $P < .001$). Although overweight boys were as tall as normal-weight boys, overweight girls were taller than normal-weight girls (162.3 ±9.1 cm versus 155.6 ± 1.0 cm, $P = .001$), **Tables II** and **III**.

Before intervention, overweight children had a higher resting heart rate (HR) than normal-weight children (89 ± 12 bpm versus 85 ± 14 bpm, $P = .016$) and a lower post-test HR (114 ± 9 bpm versus 140 ± 22 bpm, $P < .001$). After intervention, resting HR in overweight children had decreased to similar values as in normal-weight children (83 ± 13 bpm versus 85 ± 14 bpm, $P = .205$), and their post-test HR remained similar to that of the start of the program, still being substantially lower than in normal-weight children (114 ± 23 bpm versus 140 ± 22 bpm, $P < .001$) (**Table II**).

In multivariate regression analysis and at both time points BMI-SDS ($\beta = -0.391/-0.366$), height ($\beta = 0.349/0.404$) and ΔHR ($\beta = 0.311/0.272$) were independent predictors ($P < .001$

Table I. Characteristics of study groups at start and at end of the weight reduction program in overweight children and adolescents

	Overweight (n = 113)					
	Start	End	*P*	Nonoverweight (control subjects) (n = 353)	*P*†	*P*‡
Age in years	12.9 (2.0)			12.7 (3.1)	.635	
Sex, n (%)						
Male	49 (43%)	49 (43%)		187 (53%)		
Female	64 (57%)	64 (57%)		166 (47%)		
Height, cm	162.5 (11.5)			159.0 (16.5)	.002	
Weight, kg	80.9 (19.8)	75.6 (19.0)	≤.001	47.4 (14.5)	≤.001	≤.001
BMI, centile	98.2 (2.1)	96.8 (3.8)	≤.001	45.1 (26.7)	≤.001	≤.001
BMI-SDS	2.4 (0.5)	2.1 (0.6)	≤.001	−0.2 (0.9)	≤.001	≤.001
Fat %	35.9 (6.8)	33.5 (7.1.)	≤.001			
Length of ward, d	27.8 (6.8)					

Values are presented as absolute numbers and percentage or mean (SD).
P values refer to comparison of data at start and at end in overweight children.
†*P* values refer to comparison of data in overweight children at start and control subjects.
‡*P* values refer to comparison of data in overweight children at end and control subjects.

for each variable) of the 6MWD (r^2 = 0.338 and r^2 = 0.349, respectively) in overweight children and adolescents. When grouped by sex, △HR was no more predictive for the 6MWD at both time points in overweight males but remained predictive in overweight females (β = 0.467 [$P < .001$] and β = 0.319 [$P = .006$]).

In normal-weight children and adolescents, height (β = 0.592, $P < .001$) and age (β = −0.216, $P = .040$) but neither BMI-SDS nor △HR ($P > 0.05$) were independent predictors of the 6MWD.

Discussion

The most important finding of our study is an increasing 6MWD during weight loss indicating improvement of physical fitness and decreased metabolic demand during daily activities. Children with lower BMI and those with greater increments in ΔHR during the 6MWT were able to walk longer distances.

Excellent reliability and validity of the 6MWT has been demonstrated in healthy normal-weight children.[15] Similarly, good reproducibility of the 6MWDs has been demonstrated in overweight children. The bias (the mean difference between the two paired means) of two tests performed within mean 4 days was 2.8 m.[17] Therefore, a learning effect, accounting for the greater 6MWDs during the second 6MWT in the overweight participants of our study, appears to be very unlikely because they walked 36 m farther in the postintervention test.

The BMI allows assessing overweight and obesity in children most effectively. It correlates with adiposity[21,22] and complications of childhood overweight.[23-25] When converted to *z*-scores, individual BMI values can be used as an outcome measure for weight development. Despite using a different study setting and duration of intervention, similar weight reduction and increase of 6MWD was reported by Calders.[16] In their retrospective analysis, BMI-SDS was the most dominant predictor of the variability in 6MWD at admission and after 3 months. A drop in BMI-SDS during intervention may therefore serve as a surrogate for better exercise performance.

Decreased physical activity and a more sedentary lifestyle as well as increased fat mass affect exercise performance in a negative way.[26,27] Furthermore, maximum heart rate during exercise is known to be lower in overweight adolescents, presumably because of both lack of fitness and overweight itself.[28] In our study, resting heart rates in overweight children decreased to normal values on the second 6MWT. Interestingly, the impact of weight loss on resting heart rate and thus resting energy consumption was very pronounced in girls. We assume that in them, weight loss primarily led to a reduction of metabolic cost of excess adiposity, thereby

Table II. Six-minute walk distance (6MWD) and heart rate difference (ΔHR) of overweight and nonoverweight children (control subjects) at start and at end of the weight reduction program in overweight children and adolescents

	Overweight (n = 113)					
	Start	End	*P*	Control Subjects (n = 353)	*P*†	*P*‡
6MWD, m	631.3 (87.9)	667.2 (90.2)	≤.001	674.7 (69.8)	≤.001	.261
Resting heart rate, beats/min	89 (12)	83 (13)	≤.001	85 (14)	.016	.205
Heart rate after 6MWT	114 (9)	114 (23)	.728	140 (22)	≤.001	≤.001
ΔHR	25.1 (16.8)	31.6 (22.7)	.004	54.8 (21.7)	≤.001	≤.001

Values are presented as mean (SD).
P values refer to comparison of data at start and at end in overweight children.
†*P* values refer to comparison of data in overweight children at start and control subjects.
‡*P* values refer to comparison of data in overweight children at end and control subjects.

Table III. Characteristics of study groups at start and at end of the weight reduction program, broken down by sex

	Overweight girls (n = 64)						Overweight boys (n = 49)					
	Start	End	P	Nonoverweight girls (n = 166)	P†	P‡	Start	End	P	Nonoverweight boys (n = 187)	P†	P‡
Height	162.3 (9.1)			155.7 (14.1)	.001		162.7 (14.2)			162.0 (18.0)	.781	
Weight	81.0 (17.8)	76.8 (17.3)	<.001	45.4 (12.7)	<.001	<.001	78.7 (22.2)	74.0 (21.0)	<.001	49.8 (15.6)	<.001	<.001
BMI-SDS	2.4 (0.6)	2.2 (0.6)	<.001	−0.2 (0.9)	<.001	<.001	2.3 (0.5)	2.0 (0.6)	<.001	−0.2 (0.8)	<.001	<.001
6MWD	620.9 (71.4)	659.6 (69.2)	<.001	658.8 (54.5)	<.001	.955	644.9 (104.9)	677.2 (111.8)	.004	688.9 (78.5)	.001	.400
HF before test	88.3 (11.0)	80.0 (11.2)	<.001	86.1 (13.7)	.247	.001	89.6 (14.1)	87.4 (15.0)	.379	84.3 (15.5)	.032	.209
HF after test	116.0 (20.2)	118.5 (22.6)	.399	145.5 (21.3)	<.001	<.001	111.4 (17.1)	110.0 (24.3)	.701	135.0 (22.7)	<.001	<.001
ΔHF	27.7 (16.5)	38.5 (21.0)	<.001	59.4 (21.9)	<.001	<.001	21.8 (16.8)	22.6 (21.8)	.838	50.6 (20.8)	<.001	<.001

Values are presented as mean (SD).
ΔHF, heart rate difference.
P values refer to comparison of data at start and at end in overweight girls/boys.
†*P* values refer to comparison of data in overweight girls/boys and controls at start of the program.
‡*P* values refer to comparison of data in overweight girls/boys and controls at end of the program.

increasing cardiorespiratory reserve to some extent (resulting in higher 6MWDs). Continued overweight presumably counted for the still lower post-test HR in both sexes. Of note, post-test heart rate did not differ between the first and the second tests in overweight children of our study and was substantially lower than in normal-weight children performing a 6MWT. Nevertheless, they managed to increase their 6MWD from 93% to 99% that of normal-weight children after short time intervention. Looking at the energetics of walking might provide an explanation: In overweight individuals, the "metabolic cost of walking" has been shown to be much lower than one would expect from experiments in normal-weight participants bearing excess weight during walking. Overweight adults somehow manage to "optimize" energy consumption, making walking more efficient.[29-31] This might equally apply to children and adolescents. Therefore, apparently small changes in body weight, body composition, and probably improved fitness may be sufficient to shift walking performance to a higher level in overweight children and adolescents.

In general, the use of a measuring wheel in a 6MWT appears to yield somewhat greater 6MWDs than those of "conventional" 6MWTs, at least in healthy nonoverweight children and adolescents, although no head-to-head comparison of the two test modes has been performed so far.[12,32] Reported 6MWDs of "conventional" 6MWTs in overweight children and adolescents are considerably lower than those of our study population.[16,17] We believe that a measuring wheel, in contrast to simply walking a maximum distance, represents an intrinsic incentive for the participants. The ΔHR during the conventional 6MWT has been reported to be independently associated with 6MWD in normal-weight children[11] but not if an incentive device is used (unpublished own observation).[12] This incentive device might thus potentially lead to more comparable levels of effort put into the walk. In the overweight girls, however, the effects of this proposed incentive stimulus appear to be less important, and unknown motivational factors might come into play. Overweight children should be encouraged to enjoy physical activity, and tests must focus on their special needs. In that respect, consecutive 6MWTs appear to be of value, and measurable improvement can be achieved within relatively short-time paralleling weight loss.

Some limitations might be taken into consideration when interpreting the data of our study. One of them is the lack of a longitudinal overweight control group. Nevertheless, compared with the minimal learning effect in 6MWT reported by others,[16] this limitation appears insubstantial. Obviously, the 6MWD shows a ceiling effect caused by morphometric factors such as leg (stride) length. Height is the best variable in normal-weight children performing a 6MWT, with nearly "perfect" correlation to leg length and thus stride length, with $r^2 = 0.952$ (unpublished own observation).[11,12] Clearly, height is not an important actuating factor because it is expected not to change substantially during a short-time intervention. However, when conducting long-time intervention studies using 6MWTs as an outcome measure in children and adolescents, growth must be incorporated into analysis. More elaborate methods, such as cardiopulmonary exercise testing and sports-motor tests, might be necessary to further elucidate possible impacts of body weight and shape on physical condition and motor abilities in overweight children. The use of an intrinsic incentive device may preclude comparability with data derived from studies using conventional 6MWTs.

The 6MWT represents a practical, simple, and reliable assessment tool of exercise performance in overweight children and adolescents. The 6MWD increases during a weight reduction program and indicates improvement of physical fitness and decreased metabolic demand during daily activities. ■

Submitted for publication Mar 21, 2010; last revision received Jul 12, 2010; accepted Aug 17, 2010.

Reprint requests: Dr Ralf Geiger, MD, PhD, Department of Pediatrics, Clinical Division of Cardiology, Pulmology, Allergology, and Cystic Fibrosis, Innsbruck Medical University, Anichstrasse 35, 6020 Innsbruck/Austria. E-mail: ralf.geiger@i-med.ac.at

References

1. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. JAMA 2002;288:1728-32.

2. Strauss RS, Pollack HA. Epidemic increase in childhood overweight, 1986-1998. JAMA 2001;286:2845-8.
3. Jolliffe D. Extent of overweight among US children and adolescents from 1971 to 2000. Int J Obes Relat Metab Disord 2004;28:4-9.
4. Mantzoros CS, Rifas-Shiman SL, Williams CJ, Fargnoli JL, Kelesidis T, Gillman MW. Cord blood leptin and adiponectin as predictors of adiposity in children at 3 years of age: a prospective cohort study. Pediatrics 2009;123:682.
5. Dietz WH, Robinson TN. Clinical practice: overweight children and adolescents. N Engl J Med 2005;352:2100-9.
6. Lohman TG, Ring K, Pfeiffer K, Camhi S, Arredondo E, Pratt C, et al. Relationships among fitness, body composition, and physical activity. Med Sci Sports Exerc 2008;40:1163-70.
7. Nobili V, Manco M, Devito R, Di Ciommo V, Comparcola D, Sartorelli MR, et al. Lifestyle intervention and antioxidant therapy in children with nonalcoholic fatty liver disease: a randomized, controlled trial. Hepatology 2008;48:119-28.
8. Korsten-Reck U, Kaspar T, Korsten K, Kromeyer-Hauschild K, Bös K, Berg A, et al. Motor abilities and aerobic fitness of obese children. Int J Sports Med 2007;28:762-7.
9. Nixon PA, Joswiak ML, Fricker FJ. A six-minute walk test for assessing exercise tolerance in severely ill children. J Pediatr 1996;129:362-6.
10. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardio respiratory domain. Chest 2001;119:256-70.
11. Li AM, Yin J, Au JT, So HK, Tsang T, Wong E, et al. Standard reference for the six-minute-walk test in healthy children aged 7 to 16 years. Am J Respir Crit Care Med 2007;176:174-80.
12. Geiger R, Strasak A, Treml B, Gasser K, Kleinsasser A, Fischer V, et al. Six-minute walk test in children and adolescents. J Pediatr 2007;150:395-9.
13. Gulmans VA, van Veldhoven NH, de Meer K, Helder PJ. The six-minute walking distance in children with cystic fibrosis: reliability and validity. Pediatr Pulmonol 1996;22:85-90.
14. Larsson UE, Reynisdottir S. The six-minute walk test in outpatients with obesity: reproducibility and known group validity. Physiother Res Int 2008;13:84-93.
15. Li AM, Yin J, Yu CCW, Tsang T, So HK, Wong E, et al. The six-minute walk test in healthy children: reliability and validity. Eur Respir J 2005; 25:1057-60.
16. Calders P, Deforche B, Verschelde S, Bouckaert J, Chevalier F, Bassle E, et al. Predictors of 6-minute walk test and 12-minute walk/run test in obese children and adolescents. Eur J Pediatr 2008;167:563-8.
17. Morinder G, Mattsson E, Sollander C, Evers Larsson U, Marcus C. Six-minute walk test in obese children and adolescents: reproducibility and validity. Physioth Re Int 2009;14:91-104.
18. Summerbell CD, Ashton V, Campbell KJ, Edmunds L, Kelly S, Waters E. Interventions for treating obesity in children. Cochrane Database Syst Rev 2003;3:CD001872.
19. Kromeyer-Hauschild K, Wabitsch M, Kunze D. Perzentile für den Body-Mass-Index für das Kinder- und Jugendalter unter Heranziehung verschiedener deutscher Stichproben. Monatsschr Kinderheilkd 2001;149: 807-18.
20. American Thoracic Society. ATS Statement: Guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002;166:111-7.
21. Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. Br J Nutr 1991; 65:105-14.
22. Freedman DS, Wang J, Maynard LM, Thornton JC, Mei Z, Pierson RN, et al. Relation of BMI to fat and fat-free mass among children and adolescents. Int J Obes Relat Metab Disord 2005;29:1-8.
23. Gidding SS, Bao W, Srinivasan SR, Berenson GS. Effects of secular trends in obesity on coronary risk factors in children: the Bogalusa Heart Study. J Pediatr 1995;127:868-74.
24. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. Pediatrics 1999;103:1175-82.
25. Raitakari OT, Porkka KV, Räsänen L, Viikari JS. Clustering and six year cluster-tracking of serum total cholesterol, HDL-cholesterol and diastolic blood pressure in children and young adults: the Cardiovascular Risk in Young Finns Study. J Clin Epidemiol 1994;47:1085-93.
26. Haerens L, Deforche B, Maes L, Cardon G, Debourdehaudhuij J. Physical activity and endurance in normal weight versus overweight boys and girls. J Sports Med Phys Fitness 2007;47:344-50.
27. Kimm SY, Glynn NW, Kriska AM, Barton BA, Kronsberg SS, Daniels SR, et al. Decline in physical activity in black girls and white girls during adolescence. N Engl J Med 2002;347:709-15.
28. Norman AC, Drinkard B, McDuffie JR, Ghorbani S, Yanoff LB, Yanovski JA. Influence of excess adiposity on exercise fitness and performance in overweight children and adolescents. Pediatrics 2005;115:690-6.
29. Browning RC, Baker EA, Herron JA, Kram R. Effects of obesity and sex on the energetic cost and preferred speed of walking. J Appl Physiol 2006; 100:390-8.
30. Browning RC, Kram R. Pound for pound: working out how obesity influences the energetics of walking. J Appl Physiol 2009;106:1755-6.
31. Peyrot N, Thivel D, Isacco L, Morin JB, Duche P, Belli A. Do mechanical gait parameters explain the higher metabolic cost of walking in obese adolescents? J Appl Physiol 2009;106:1763-70.
32. Lammers AE, Hislop AA, Flynn Y, Haworth SG. The 6-minute walk test: normal values for children of 4-11 years of age. Arch Dis Child 2008;93: 464-8.