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# Six-minute walk test in children with chronic conditions

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## ABSTRACT

**Objectives** The 6-minute walk test (6MWT) is a frequently used indicator of functional exercise capacity. The goals of this study were to compare the 6-minute walk performance of three paediatric patient groups with that of healthy peers, to assess differences between published reference values and to investigate which anthropometric characteristics best predict 6-minute walk performance.

**Methods** 47 children with haemophilia (mean (SD) age 12.5 (2.9) years), 44 with juvenile idiopathic arthritis (JIA) (mean age 9.3 (2.2) years) and 22 with spina bifida (SB) (mean age 10.3 (3.1) years) were included. Subjects performed a 6MWT, and the distance walked (6MWD) was compared with published reference values.

**Results** The haemophilia, JIA and SB patients achieved 90%–92%, 72%–75% and 60%–62% of predicted walking distances, respectively. There were significant associations between 6MWD and age, height and weight in the haemophilia group and 6MWD and height in the JIA group. None of the anthropometric variables was significantly related to 6MWD in the SB group. All anthropometric variables were strongly correlated with walking distance–body weight product (6Mwork) in all groups. Height explained 24% (haemophilia) and 11% (JIA) of the variance in 6MWD and 84% (haemophilia), 78% (JIA) and 73% (SB) of the variance in 6Mwork.

**Conclusions** Walking distances of children with haemophilia, JIA and SB are significantly reduced compared with healthy references. Walking distance–body weight product seems to be a better outcome measure of the 6MWT compared with distance walked alone. Height is the best predictor of 6MWD and 6Mwork.

The 6-minute walk test (6MWT) is a self-paced, submaximal exercise test used to assess functional exercise capacity in patients with chronic diseases. It has been widely used in adults, most extensively in patients with cardiopulmonary diseases, and is currently the test of choice when using a functional walk test for clinical or research purposes.<sup>1</sup> The test is well-standardised and easy to administer in clinical settings. The 6MWT is increasingly being utilised in paediatric populations and has been found to be a valid estimate of physical fitness in children with severe cardiopulmonary disease, cystic fibrosis and JIA.<sup>2–4</sup> The test has shown good reliability<sup>5–7</sup> and is frequently employed to assess the response to interventions.<sup>7–9</sup> Recently, reference values and prediction equations from healthy children have been published for the 6-minute walking distance (6MWD), making it possible to determine the extent of exercise intolerance for individual patients.<sup>5–10–12</sup> However, it is not clear whether the different published prediction equations will yield the same

results for individual patients, as there are methodological differences in the studies and the different prediction equations do not contain the same anthropometric variables. Therefore, the main purpose of this study was to compare the 6MWD of paediatric patients with reference values of healthy subjects derived from previous studies and hereby assess the differences in predicted walking distances.

Walking distance is accepted as the main outcome measure of the 6MWT. More recently though, an additional outcome measure was proposed for the 6MWT.<sup>6–13</sup> Chuang *et al* argued that the work of walking during the 6MWT (6Mwork) can be expressed as 6MWD × body weight and found that 6Mwork correlated significantly better with physical fitness (peak oxygen uptake during cardiopulmonary exercise testing) than did the 6MWD alone.<sup>13</sup> Age and height have been shown to be good predictors of 6MWD in healthy children and are the anthropometric variables used in reference equations for the 6MWD.<sup>10–12</sup> However, their predictive value for the 6-minute walk performance in severely ill children is unclear as these variables demonstrated no significant correlation in patients awaiting heart–lung or lung transplantation<sup>2</sup> and children with moderate to severe cystic fibrosis.<sup>6</sup> Therefore, the second aim of this study was to investigate the associations between age, height, weight, body mass index (BMI) and sex, and 6MWD and 6Mwork in children with different levels of physical impairments. For this purpose, we included three different patient groups in this study: haemophilia, juvenile idiopathic arthritis (JIA) and spina bifida (SB).

## METHODS

### Patients

Patients were selected from previous studies investigating physical fitness in children with haemophilia (Engelbert *et al*, unpublished data), juvenile idiopathic arthritis (JIA)<sup>14</sup> and spina bifida (SB).<sup>15</sup> The haemophilia patients were recruited from the “Van Creveldkliniek” of the University Medical Centre Utrecht. Patients who had a bleeding in the ankles or knees 2 weeks before assessment were excluded, as Van der Net *et al* reported a bleeding 1 day post-testing in a subject that had a bleeding in that same joint 1 week before the test.<sup>16</sup> The JIA patients were recruited from the paediatric rheumatology outpatient clinics of the Wilhelmina Children's Hospital, University Medical Centre Utrecht, The Netherlands and the University Hospital Groningen, The Netherlands. All patients were receiving local and/or systemic arthritis-related

treatment consisting of non-steroidal anti-inflammatory drugs and/or disease modifying anti-rheumatic drugs and/or immunosuppressive drugs/steroids in the last 6 months before inclusion. Patients were excluded if they had minor surgery <14 days before inclusion or major surgery <6 weeks before inclusion. The SB patients were recruited from the Wilhelmina Children's Hospital. Included were those with paralysis level L5 or below, IQ>80, age between 6 and 18 years and the ability to ambulate 500 m or more without crutches or parawalkers. Patients were excluded if they had surgery <6 months before inclusion, had monoparesis or cerebral movement impairments or were unable to speak Dutch. All patients who performed a 6MWT were included in this study. The study was approved by the local ethics committee and patients and/or parents signed informed consent.

### Anthropometry

Patients' body mass and height were determined using an electronic scale and a wall-assembled stadiometer. BMI was calculated as weight/height<sup>2</sup>.

### Six-minute walk test

The 6MWT was performed on an 8-m track in a straight corridor. Patients were instructed to walk back and forth in the corridor, covering as much distance as possible in 6 minutes at a self-chosen walking speed, but without running or jogging. The number of laps was counted with a mechanical lap counter, and time was measured with a stopwatch. The investigator stood near the starting line during the test, kept the patient informed about the time course and provided encouragements (eg, "You are doing well", "Keep up the good work") according to the American Thoracic Society (ATS) Guidelines.<sup>17</sup> The total distance covered in 6 minutes was calculated by multiplying the number of laps by 8 m and adding the distance covered in the final partial lap. Walking distance of our subjects was compared with predicted 6MWD using the prediction equations from Geiger *et al*<sup>11</sup> and the height-specific centile curves from Li *et al*.<sup>12</sup> The equations published by Li *et al* could not be used as difference in heart rate before and after the 6MWT, one of the independent variables in these equations; thus, it was not measured in our subjects. No comparison was made with the reference values from Lammers *et al*<sup>10</sup> as age of the subjects was limited to 4–11 years. A *p* value of <0.05 was considered statistically significant.

### Statistical analysis

Statistical analyses were performed with SPSS V.12.0 for Windows (SPSS, Chicago, Illinois, USA). Descriptive statistics were calculated, and the distribution of variables was checked

with the Kolmogorov–Smirnov test. All data were normally distributed with exception of age in the haemophilia group and weight, BMI and 6Mwork in the JIA group. Unpaired *t* test or the non-parametric Mann–Whitney *U* test was used to assess differences between groups. Correlation coefficients were calculated between age, height, weight, BMI and 6MWD and 6Mwork. Forward stepwise multiregression analysis was used to determine the best predictors of 6MWD and 6Mwork.

## RESULTS

### Patients

One patient with JIA and one with SB did not perform the 6MWT and were excluded from analysis. Patient characteristics are presented in table 1. The patients with haemophilia were all boys, while 35 of the 43 JIA patients and 9 of the 22 SB patients were girls. The haemophilia patients were significantly older, taller and heavier than the patients with JIA and SB (*p*<0.001). The BMI of haemophilia patients was significantly higher than that of JIA patients (*p*=0.005) but showed no significant difference from that of SB patients (*p*=0.16). Age, height, weight and BMI did not differ significantly between the JIA and SB groups. Li *et al* provided reference values for patients with heights from 1.20 to 1.80 m. Seven patients with haemophilia, three with JIA, and three with SB fell outside this range and could not be compared with references from this study.

### Six-minute walk test

The performance during the 6MWT is presented in table 2. The mean 6MWD was 628, 459 and 391 m for the haemophilia, JIA and SB groups, respectively. The haemophilia patients walked 169 and 237 m more compared with the JIA and SB patients, respectively (*p*<0.001). Patients with JIA walked 68 m more than those with SB (*p*<0.001). Distances walked did not differ significantly between boys and girls in the JIA (*p*=0.55) and SB groups (*p*=0.92).

Compared with reference values from Geiger *et al*<sup>11</sup> and Li *et al*,<sup>12</sup> the walking distances of the haemophilia, JIA and SB patients were significantly reduced (*p*<0.001). The haemophilia, JIA and SB patients, respectively, achieved 90%, 72% and 60% of the predicted distances derived from Li *et al* and 92%, 75% and 62% of the predicted distances derived from Geiger *et al*. Of the haemophilia patients, five and seven exceeded the distance predicted by Li *et al* and Geiger *et al*, respectively. Differences in percentage predicted walking distance derived from these studies were on average 2.25 (3.4%). The correlation between the percentages of predicted according to Geiger *et al* and Li *et al* was highly significant (*r*=0.97, *p*<0.0001).

Correlation analysis revealed that 6MWD was significantly associated with age (*r*=0.49, *p*<0.001), height (*r*=0.49,

**Table 1** Patient characteristics

|                          | Haemophilia (n = 47)  | JIA (n = 44)                 | SB (n = 22)      |
|--------------------------|---|------------------------------|------------------|
| Sex (male/female)        | 47/0  | 9/35                         | 13/9             |
| Age (years)              | 12.5 (2.9)  | 9.3 (2.2)                    | 10.3 (3.1)       |
| Height (m)               | 1.60 (0.2)  | 1.40 (0.1)                   | 1.40 (0.2)       |
| Weight (kg)              | 50.8 (15.8)   | 34.2 (10.6)                  | 37.3 (13)        |
| BMI (kg/m <sup>2</sup> ) | 19.6 ± 3.1  | 17.7 (2.8)                   | 18.4 (2.9)       |
| Disease subclass, no.    | Haemophilia A 42<br>Haemophilia B 4<br>Haemophilia B Leyden 1 | oJIA 19<br>pJIA 21<br>sJIA 4 | MMC 15<br>LMMC 7 |

JIA, juvenile idiopathic arthritis; LMMC, lypomyelomeningocele; MMC, myelomeningocele; oJIA, oligoarticular juvenile idiopathic arthritis; pJIA, polyarticular juvenile idiopathic arthritis; SB, spina bifida; sJIA, systemic juvenile idiopathic arthritis. Values are mean (SD) unless indicated otherwise.

**Table 2** Measured and predicted 6MWD

|                           | Haemophilia (n = 47)    | JIA (n = 44)           | SB (n = 22)            |
|---------------------------|-------------------------|------------------------|------------------------|
| 6MWD (m)                  | 628 (59) (515–763)      | 459 (63) (320–584)     | 391 (61) (285–553)     |
| Predicted 6MWD Li (m)     | 691 (18) (650–723)      | 642 (18) (610–690)     | 664 (26) (625–715)     |
| Predicted 6MWD Geiger (m) | 682 (38) (599–733)      | 617 (46) (531–690)     | 634 (57) (529–716)     |
| % Predicted Li            | 90.2 (7.7) (75.7–107.5) | 71.8 (9.4) (50.8–88.5) | 60.0 (9.4) (47.9–86.0) |
| % Predicted Geiger        | 92.2 (7.5) (75.6–107.2) | 74.5 (9.7) (52.8–90.1) | 62.2 (9.4) (48.1–83.4) |

6MWD, 6-minute walking distance; % predicted Geiger, 6MWD as a percentage of the reference values attained from Geiger *et al*;  
% predicted Li, 6MWD as a percentage of the reference values attained from Li *et al*.  
Values are mean (SD) (range).

$p = 0.001$ ) and weight ( $0.34$   $p = 0.018$ ) in the haemophilia group and with height ( $r = 0.34$ ,  $p = 0.025$ ) in the JIA group. Forward stepwise multiregression analysis showed height to be the best predictor of 6MWD, explaining 24% and 11% of the variance in the haemophilia and JIA groups, respectively. Age, height, weight and BMI showed no significant correlation with 6MWD in the SB group. All anthropometric variables were strongly correlated with 6MWD in all patient groups, height showing the highest correlation coefficients (0.92, 0.88 and 0.86 for haemophilia, JIA and SB, respectively). Height alone explained 83.7% (haemophilia), 77.5% (JIA) and 73% (SB) of the variance in 6MWD. Figures 1 and 2 show the relationship between height and 6MWD and 6MWD.

## DISCUSSION

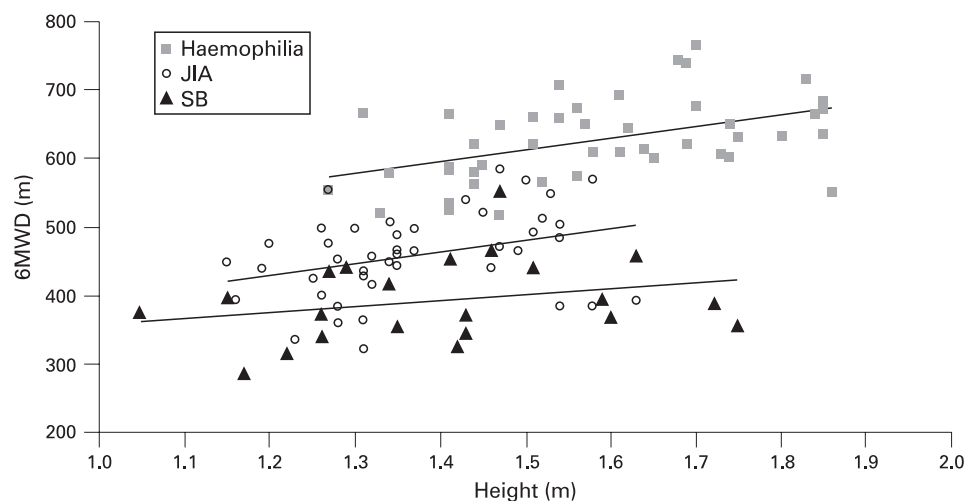
This study demonstrated that the 6MWD of patients with haemophilia, JIA and SB is significantly reduced compared with healthy subjects. The predicted walking distances attained from two previous studies differed very little from each other and were 90%–92%, 72%–75% and 60%–62% of predicted for the haemophilia, JIA and SB patients, respectively.<sup>11–12</sup> Moreover, height proved to be the best predictor of 6MWD and 6MWD.

The 6MWD is a submaximal exercise test and is an indicator of functional exercise capacity. The children with haemophilia showed minimal reduction in 6MWD compared with reference values, indicating that their physical ability approaches that of the healthy population. This is in accordance with a previous study showing normal physical fitness and an activity level comparable with that of healthy peers in 13 boys with severe haemophilia A.<sup>16</sup> The distance walked by the JIA patients was 25%–27% less than predicted. This is in line with reports of children with JIA being less physically fit<sup>18</sup> and less physically

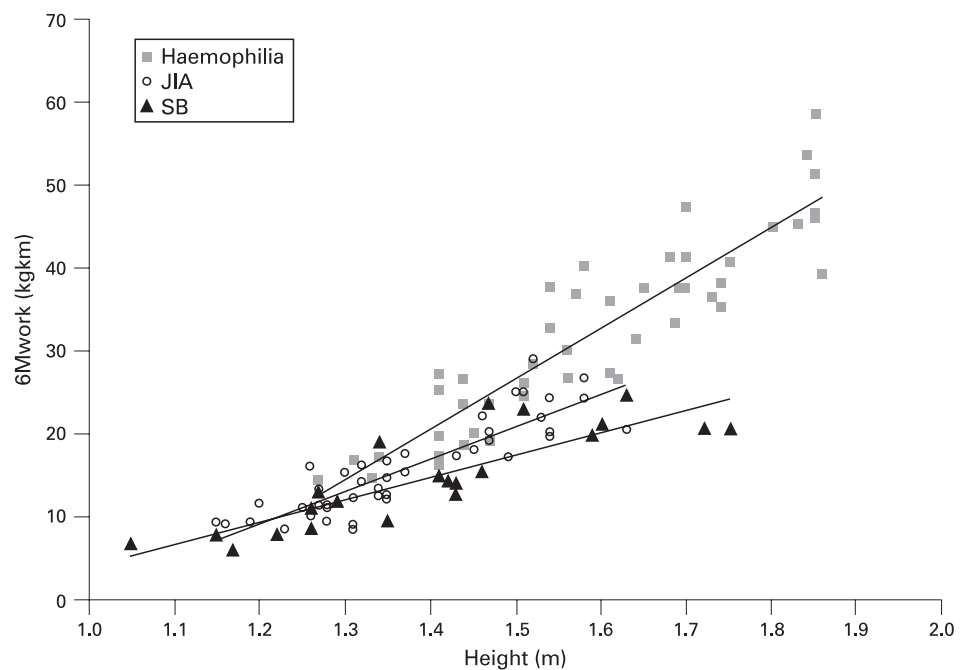
active<sup>19</sup> than healthy controls. Of the three patient groups, those with SB covered the least distance, achieving merely 60%–62% of the predicted distance. Schoenmakers *et al*<sup>15</sup> studied the same cohort of patients with SB that were included in the present study and found muscle strength, aerobic capacity and physical activity to be significantly reduced compared with reference values. Furthermore, Schoenmakers *et al* suggested that the reduced muscle strength in the lower extremities caused an inefficient gait that might be energy consuming.<sup>15</sup>

There were some methodological differences in the studies we attained reference values from.<sup>11–12</sup> Geiger *et al*<sup>11</sup> studied Caucasians aged 3–18 years, while Li *et al*<sup>12</sup> studied Chinese children aged 7–16 years. There is limited data on ethnic variations in 6MWD. A study of 35 healthy adults revealed that regression equations for the 6MWD derived from Caucasian subjects overestimated the 6MWD in Singaporean Chinese.<sup>20</sup> A study assessing 6MWD in paediatric subjects with different ethnic backgrounds found no significant differences in 6MWD between the ethnic groups.<sup>10</sup> The course length was 100 ft (30 m) in Geiger *et al* and 20 m in Li *et al*. A walking course of 30 m is recommended by the American Thoracic Society. However, a multicenter study found no significant effect of the length of straight courses ranging from 50 to 164 ft (15 to 50 m).<sup>17</sup> Walking distance in our subjects may have been underestimated as we used an 8-m track in a straight corridor. Subjects were encouraged in a standardised<sup>17</sup> manner in both our study and the reference studies. Geiger *et al* additionally implemented a measuring wheel that displayed the instantaneous walking distance as a motivational tool. The effect of this measuring wheel on 6MWD remains unclear. Despite these methodological differences, percentages predicted walking distance derived from these studies differed very little (2%–3%). The advantage of the height-specific centile curves published by

**Figure 1** Association between 6-minute walking distance (6MWD) and height. JIA, juvenile idiopathic arthritis; SB, spina bifida.



**Figure 2** Association between 6Mwork and height. 6Mwork, product of 6-minute walking distance (km) and weight (kg).



Li *et al* is that they are easy to use. However, references are limited to subjects with a height range of 1.20 to 1.80 m. The reference equations published by Geiger *et al* incorporate the variables age and height and are applicable to all subjects between the age of 3 and 18 years. Children with chronic conditions are often retarded in growth. Reference values based on age might, in these cases, lead to overestimation of the 6MWD.

We studied the association among age, height, weight, BMI and 6MWD and found height to be the best predictor of 6MWD in the haemophilia and JIA group. Li *et al* reported comparable results in healthy subjects.<sup>12</sup> Lammers *et al*, however, found that 44% of the variation in walking distance could be explained by age, height and weight, age accounting for 41% of the variation.<sup>10</sup> In the SB group, none of the anthropometric variables was significantly related to 6MWD. It seems that

the effect of anthropometric characteristics on 6MWD is superseded by the severity of the condition. This is supported by earlier studies in children with CF and severe cardiopulmonary disease.<sup>2,6</sup> When 6Mwork was considered, height explained 84%, 78% and 73% of the variation in the haemophilia, JIA and SB group, respectively. Chuang *et al* stated that walking distance-body weight product reflects the work of walking and showed that 6MWork correlates better with physical fitness than 6MWD.<sup>13</sup>

In conclusion, the availability of reference values for paediatric populations facilitates the interpretation of the 6MWT. We found that the percentage predicted walking distance derived from two different studies provide comparable results. Children with haemophilia, JIA and SB achieved on average 90%, 75% and 60% of predicted walking distance, respectively. This study demonstrates that 6Mwork enhances the utility of the 6MWT in clinical practise by improving the interpretability of the 6MWT through a wide range of levels of physical impairment. Finally, we showed that height is the best predictor of both 6MWD and 6Mwork.

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**Competing interests** None.

## REFERENCES

1. Solway S, Brooks D, Lacasse Y, *et al*. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. *Chest* 2001;**119**:256–70.
2. 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.
3. Gulmans VA, van Veldhoven NH, de Meer K, *et al*. The six-minute walking test in children with cystic fibrosis: reliability and validity. *Pediatr Pulmonol* 1996;**22**:85–9.
4. Lelieveld OT, Takken T, van der Net J, *et al*. Validity of the 6-minute walking test in juvenile idiopathic arthritis. *Arthritis Rheum* 2005;**53**:304–7.
5. Li AM, Yin J, Yu CC, *et al*. The six-minute walk test in healthy children: reliability and validity. *Eur Respir J* 2005;**25**:1057–60.
6. Cunha MT, Rozov T, de Oliveira RC, *et al*. Six-minute walk test in children and adolescents with cystic fibrosis. *Pediatr Pulmonol* 2006;**41**:618–22.

## What is already known on this topic

- ▶ The 6-minute walk test (6MWT) is a self-paced, submaximal endurance test that is increasingly being used to assess functional capacity in paediatric populations.
- ▶ Walking distance has been the preferred outcome measure of the 6MWT; however, distance walked  $\times$  body weight (6Mwork) might be an additional outcome measure.

## What this study adds

- ▶ This study provides data on the 6-minute walking distance (6MWD) of patients with haemophilia, juvenile idiopathic arthritis and spina bifida compared with reference values.
- ▶ Percentage predicted walking distances derived from two different studies provide comparable results.
- ▶ Height is the anthropometric variable that best predicts 6MWD and 6Mwork.

7. **Moalla W**, Gauthier R, Maingourd Y, *et al*. Six-minute walking test to assess exercise tolerance and cardiorespiratory responses during training program in children with congenital heart disease. *Int J Sports Med* 2005;**26**:756–62.
8. **Humpl T**, Reyes JT, Holtby H, *et al*. Beneficial effect of oral sildenafil therapy on childhood pulmonary arterial hypertension: twelve-month clinical trial of a single-drug, open-label, pilot study. *Circulation* 2005;**111**:3274–80.
9. **Takken T**, van der Net J, Helders PJ. Do juvenile idiopathic arthritis patients benefit from an exercise program? A pilot study. *Arthritis Rheum* 2001;**45**:81–5.
10. **Lammers AE**, Hislop AA, Flynn Y, *et al*. The six-minute walk test: normal values for children of 4–11 years of age. *Arch Dis Child*. Published Online First: 3 Aug 2007. doi:10.1136/adc.2007.123653
11. **Geiger R**, Strasak A, Trembl B, *et al*. Six-minute walk test in children and adolescents. *J Pediatr* 2007;**150**:395–9.
12. **Li AM**, Yin J, Au JT, *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.
13. **Chuang ML**, Lin IF, Wasserman K. The body weight-walking distance product as related to lung function, anaerobic threshold and peak  $\text{Vo}_2$  in COPD patients. *Respir Med* 2001;**95**:618–26.
14. **Takken T**, van der Net J, Kuis W, *et al*. Physical activity and health related physical fitness in children with juvenile idiopathic arthritis. *Ann Rheum Dis* 2003;**62**:885–9.
15. **Schoenmakers MAGC**, de Groot JF, Gorter JW, *et al*. Muscle strength, aerobic capacity and physical activity in independent ambulating children with lumbosacral spina bifida. *Disabil Rehabil* 2009;**31**:259–66.
16. **van der Net J**, Vos RC, Engelbert RH, *et al*. Physical fitness, functional ability and quality of life in children with severe haemophilia: a pilot study. *Haemophilia* 2006;**12**:494–9.
17. **ATS statement: guidelines for the six-minute walk test**. *Am J Respir Crit Care Med* 2002;**166**:111–7.
18. **Takken T**, Hemel A, van der Net J, *et al*. Aerobic fitness in children with juvenile idiopathic arthritis: a systematic review. *J Rheumatol* 2002;**29**:2643–7.
19. **Henderson CJ**, Lovell DJ, Specker BL, *et al*. Physical activity in children with juvenile rheumatoid arthritis: quantification and evaluation. *Arthritis Care Res* 1995;**8**:114–9.
20. **Poh H**, Eastwood PR, Cecins NM, *et al*. Six-minute walk distance in healthy Singaporean adults cannot be predicted using reference equations derived from Caucasian populations. *Respirology* 2006;**11**:211–6.