Six-Minute Walk Test (6MWT) In Early Onset Scoliosis (EOS)

What does it tell us?
How can I use it in my practice?

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Disclosure

- Noriaki Kawakami
  - NPO Japan Spinal Deformity Institute (JSDI) (a, e)
  - Medtronic (b)
  - Kisco (b)
  - EOS imaging (a)

- Hiroko Matsumoto
  - SRS (a)
  - POSNA (a)
  - Japan Spinal Deformity Institute (JSDI) (a, b)
  - CSSG (b)

- Gregory Redding
  - No relationship

No relevant financial relationships for this presentation
6-Minute Walk Test (6MWT)

Assess the submaximal level of functional capacity. 
⇒ considered a major predictor of quality of life (Li 2007)

- To evaluate functional capacity to exercise in several cardiopulmonary and neuromuscular conditions (Chetta 2001, Kerem 2005, Moalla)

- To evaluate effect of a given treatment or rehabilitation program (Li 2005, Enright 2003)
American Thoracic Society

ATS Statement: Guidelines for the Six-Minute Walk Test

This Official Statement of the American Thoracic Society was approved by the ATS Board of Directors
March 2002

- Technical aspects of the 6MWT to standardize

Location: indoors, flat, straight, corridor with a hard surface 30 meter (20-50 m) in length.

Patient preparation:
- Comfortable clothing with shoes for walking.
- Usual walking aids during the test (cane, walker, etc.).

Measurements:
- Sit at rest in a chair for 10 minutes before the test starts.
- **Walk as far as possible for 6 minutes, but not run or jog**
- Borg scale: baseline dyspnea and overall fatigue
- Heart rate, respiratory rate, SaO₂

TABLE 2. THE BORG SCALE

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
</tr>
<tr>
<td>0.5</td>
<td>Very, very slight (just noticeable)</td>
</tr>
<tr>
<td>1</td>
<td>Very slight</td>
</tr>
<tr>
<td>2</td>
<td>Slight (light)</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat severe</td>
</tr>
<tr>
<td>5</td>
<td>Severe (heavy)</td>
</tr>
<tr>
<td>6</td>
<td>Very severe</td>
</tr>
<tr>
<td>7</td>
<td>Very, very severe (maximal)</td>
</tr>
</tbody>
</table>

Easy to do in the outpatient setting
6MWT for Evaluation of Walking Ability in Neuromuscular conditions

THE 6-MINUTE WALK TEST AND OTHER ENDPOINTS IN DUCHENNE MUSCULAR DYSTROPHY: LONGITUDINAL NATURAL HISTORY OBSERVATIONS OVER 48 WEEKS FROM A MULTICENTER STUDY
CRAIG M. MCDONALD, MD,¹ ERIK K. HENRICSON, MPH,¹ R. TED ABRESCH, MS,¹ JULAINE M. FLORENCE, PhD,² MICHELLE EAGLE, PhD,³ EDUARD GAPPMAIER, PhD,⁴ ALLAN M. GLANZMAN, DPT,⁵ for the PTC124-GD-007-DMD STUDY GROUP,* ROBERT SPIEGEL, MD,⁶ JAY BARTH, MD,⁶ GARY ELFING, MS,⁶ ALLEN REHA, MS,⁶ and STUART PELTZ, PhD⁶

DEVELOPMENTAL MEDICINE & CHILD NEUROLOGY

Walking ability and predictors of performance on the 6-minute walk test in adults with spastic cerebral palsy
GRETHE MAANUM¹ | REIDUN JAHNSEN¹,² | KATHRINE F FRØSLIE¹,²,³ | KERSTIN L LARSEN¹ | ANNE KELLER⁴

6MWT works well as a predictor of walking ability in patients with CP and Duchenne muscular dystrophy.
Healthy 328 children (54% male) aged 4 to 11 years

- **6MWD**: Linear relationship up to a weight of 30 kg and a height of 130 cm
- Provides **data on normal children** against which the performance of sick children and the response to therapeutic intervention can be judged
## References Values of 6MWT for Healthy Children

<table>
<thead>
<tr>
<th>References</th>
<th>Subjects (n)</th>
<th>Country of origin</th>
<th>Age (years)</th>
<th>Equations suggested</th>
<th>$r^2$</th>
<th>Test methodology</th>
<th>Predictive variables of DW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li, et al, 2005</td>
<td>1,445</td>
<td>China</td>
<td>7-16</td>
<td>DW(boys) = 554.16+(dif. HR x 1.76)+[height (cm)x1.23] DW(girls) = 526.79+(dif. HR x 1.66)+[height (cm)x0.62]</td>
<td>0.43</td>
<td>30 m corridor</td>
<td>Dif. HR and height</td>
</tr>
<tr>
<td>Geiger, et al, 2007</td>
<td>528</td>
<td>Austria</td>
<td>3-18</td>
<td>DW(boys) = 196.72+(39.81 x age) - (1.36 x age$^2$ + 132.28 x height) DW(girls) = 188.61+(51.50 x age) - (1.86 x age$^2$ + 86.10 x height)</td>
<td>0.49</td>
<td>20 m corridor; equipment with a wheel to measure the distance</td>
<td>Age, body weight, and height</td>
</tr>
<tr>
<td>Lammers, et al, 2007</td>
<td>328</td>
<td>United Kingdom</td>
<td>4-11</td>
<td>Not supplied</td>
<td>-</td>
<td>30-50 m corridor</td>
<td></td>
</tr>
<tr>
<td>Priesnitz, et al, 2009</td>
<td>188</td>
<td>Brazil</td>
<td>6-12</td>
<td>DW(m) =145.343 + [11.78 x age(years)] + {262.22 x height(m)} + {0.611 x dif. HR(bpm)} - {2.684 x body weight(kg)}</td>
<td>0.37</td>
<td>30 m corridor</td>
<td>Age, height, body weight, BMI, Dif. HR</td>
</tr>
<tr>
<td>Ulrich, et al, 2013</td>
<td>496</td>
<td>Switzerland</td>
<td>5-16</td>
<td>DW(boys) = 13.40 x age(years) – 2.16 x body weight(kg) + 185.53 x height(m) + 276.92 DW(girls) = 372.3 x height(m) – 2.635 x body weight(kg) + 172.05</td>
<td>?</td>
<td>30 m</td>
<td>BP, age, body weight, height, SpO$_2$, HR</td>
</tr>
</tbody>
</table>
6-minute Walk Test in EOS

No studies reported 6MWT test in EOS until we presented.

- 6MWT instead of PFT for small children when started rib-based device for GFS in 2009.

- **ICEOS 2017** Preop. (Kawakami, Matsumoto, Redding)
- **ICEOS 2018** Postop. (Kawakami, Matsumoto, Redding)
Pre-operative Six Minute Walk Performance in Children with Congenital Scoliosis

Noriaki Kawakami, et al. Presented at ICEOS AM in 2017

Evaluation of preop. 6MWT in 20 pts. with CS to determine the relationship between 6MWD and %FVC predicted BMI, and Cobb angle

not correlate with BMI% or %FVC predicted

correlated with Cobb angle
Summary of Preop. 6MWT in EOS with CS

• The 6MWD **reduced** in all patients, ranging from 10-30% of predicted values.

• **Absolute values of walking distance** were most useful to correlate with clinical features.
Improvement of Functional Outcome Using 6-minute walk in Patients with Congenital Scoliosis Treated by Growth Friendly Surgery: Five Years FU Study

Noriaki Kawakami, et al. Presented at ICEOS AM in 2018

**Purpose:** To investigate changes in 6MWT pre & post serial surgical treatment in congenital scoliosis

**Methods:** 44 pts. (age at surg. 5.8)

Compared 6MWD with BMI, %FVC at postop. 1, 2, & 5 yrs.

<table>
<thead>
<tr>
<th></th>
<th>Preop.</th>
<th>Immediate Postop.</th>
<th>1-year Postop.</th>
<th>2-year Postop.</th>
<th>5-year Postop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major curve (°)</td>
<td>72 ± 28</td>
<td>53 ± 23</td>
<td>56 ± 22</td>
<td>56 ± 22</td>
<td>52 ± 23</td>
</tr>
<tr>
<td>BMI (%tile)</td>
<td>53 ± 30</td>
<td>---</td>
<td>51 ± 29</td>
<td>43 ± 31</td>
<td>34 ± 27</td>
</tr>
<tr>
<td>%FVC Predicted</td>
<td>58 ± 17</td>
<td>---</td>
<td>57 ± 15</td>
<td>57 ± 15</td>
<td>54 ± 16</td>
</tr>
<tr>
<td>6-minute Walk (m)</td>
<td>344 ± 86</td>
<td>---</td>
<td>374 ± 74</td>
<td>390 ± 78</td>
<td>434 ± 80</td>
</tr>
</tbody>
</table>

**Results:** Standardized 6MWD was compromised at preop but did not worsen postoperatively.
Summary of Postop. 6MWT in EOS with CS

● Over the 5-year period of study, 6MWD increased by 86±97m (17.2m/year). (cf. normal children 16-25m/y)

● The change in FVC did not correlate with the change of 6MWD over 5 years. (p=0.30)

Improvement in 6MWT occurs despite persistently reduced lung function, suggesting improvements in balance, strength, and stride length may be more important determinants of performance by growth-friendly surgery.
Comparison of 6MWT with EOSQ-24

- Congenital EOS patients who underwent Growth-friendly surgery (VEPTR)
- Both 6MWT & EOSQ-24 performed twice
  - 1\textsuperscript{st} test: mean 3.2 yrs. from index surgery
  - 2\textsuperscript{nd} test: mean 5.3 yrs. from index surgery

<table>
<thead>
<tr>
<th></th>
<th>Preop.</th>
<th>1\textsuperscript{st} 6MWT</th>
<th>2\textsuperscript{nd} 6MWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>5.6 ± 1.5</td>
<td>8.8 ± 2.0</td>
<td>10.9 ± 2.0</td>
</tr>
<tr>
<td>Scoliosis (°)</td>
<td>68.1 ± 24.9</td>
<td>58.6 ± 23.1</td>
<td>42.9 ± 13.2</td>
</tr>
<tr>
<td>6MWD (m)</td>
<td>432</td>
<td>456</td>
<td></td>
</tr>
<tr>
<td>EOSQ-24 HRQoL</td>
<td>82 ± 12</td>
<td>81 ± 10</td>
<td></td>
</tr>
<tr>
<td>FVC (liter)</td>
<td>0.92± 0.29</td>
<td>1.11± 0.37</td>
<td></td>
</tr>
<tr>
<td>%FVC</td>
<td>58.8 ± 17.9</td>
<td>59.2 ± 17.0</td>
<td></td>
</tr>
</tbody>
</table>

N=49
6MWD correlated with Some Domains in EOSQ-24 at both the 1\textsuperscript{st} and 2\textsuperscript{nd} test

<table>
<thead>
<tr>
<th>Domain</th>
<th>1\textsuperscript{st} 6WMT</th>
<th>2\textsuperscript{nd} 6WMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Health</td>
<td>0.6053</td>
<td>0.9275</td>
</tr>
<tr>
<td>Pain/Discomfort</td>
<td>0.5694</td>
<td>0.2849</td>
</tr>
<tr>
<td>Pulmonary function</td>
<td>0.2951</td>
<td>0.9169</td>
</tr>
<tr>
<td>Transfer</td>
<td>0.3676</td>
<td>0.1018</td>
</tr>
<tr>
<td>Physical function</td>
<td>0.3606</td>
<td>0.0032</td>
</tr>
<tr>
<td>Daily living</td>
<td>0.0430</td>
<td>0.0359</td>
</tr>
<tr>
<td>Fatigue/Energy</td>
<td>0.1301</td>
<td>0.9848</td>
</tr>
<tr>
<td>Emotion</td>
<td>0.1716</td>
<td>0.3060</td>
</tr>
<tr>
<td>Parent burden</td>
<td>0.0612</td>
<td>0.2241</td>
</tr>
<tr>
<td>Financial burden</td>
<td>0.7663</td>
<td>0.1757</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>0.2867</td>
<td>0.0094</td>
</tr>
<tr>
<td>Total HRQoL</td>
<td>0.0559</td>
<td>0.1646</td>
</tr>
</tbody>
</table>

Serial growth-friendly interventions may not negatively affect QOL below their baseline preoperatively.
Assessment Tools

Radiographic modalities

Factors which should be assessed
- Trunk proportion
- Muscle strength
- Balance
- Nutritional status
- Lung function
- Cardiac function

Tools assessing general physical function

Physical function
- Radiographic
- Physiological
  - Lab exam
  - PFT
  - ECG
  - Ex. tolerance test
  - 6MWT
  - Etc.

Psychological status
- Questionnaire
- EOSQ-24
- SRS-22, 24, 30

Psychological effect
- Influence of pathology

Factors which should be assessed
- Trunk proportion
- Muscle strength
- Balance
- Nutritional status
- Lung function
- Cardiac function

Tools assessing general physical function

- Radiographic
- Physiological
Clinical Usage Based on Pros & Cons of 6MWT

- **Advantages**
  - Simple, easy to do in clinic,
  - Not require special equipment
  - Assess physical function

- **Limitations**
  - Impracticable for:
    - Non-ambulator
    - Not communicable (immature age, MR, etc.)
    - "Lack of physical strength" (can not bear 6MW)
    - No parents supportive

- 6MWT as one of routine evaluation tools
  - Patents who have GFS: Preop., at least once a year
  - Neuromuscular
  - Cardiopulmonary compromise
Unsettled Issue in 6MWT

Patients show the same 6MWD

98% at pre 6MWT
75 at pre 6MWT
78 at post 6MWT

SaO₂ (%) - 97-98% at post 6MWT
80 at pre 6MWT
112 at post 6MWT

Heart Rate (bpm) - 75 at pre 6MWT
78 at post 6MWT

How should we interpret physical function of both patients?
⇒ 6MWT should be evaluated by not only walking distance but also HR and SaO₂ at pre- and post-6MWT.
In Summary

• 6MWT may be a useful measurement tool in assessing global physical function of ADL and QOL in EOS.

• 6MWT is likely an outcome of a combination of muscle strength, balance, nutritional status, cardiac and lung function as well as by age and physical status.

• 6MWT requires further investigation to determine the weight that each parameter has on it, to identify which factor modifiable by treatment can contribute to better ADL and QOL.
Thank you for your attention.
Thank you for your attention.
6MWD correlated with Daily Living of EOSQ-24 at both the 1\textsuperscript{st} and 2\textsuperscript{nd} test (N=49).

<table>
<thead>
<tr>
<th></th>
<th>1\textsuperscript{st} 6WMT</th>
<th>2\textsuperscript{nd} 6WMT</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Health</td>
<td>75±18</td>
<td>71±15</td>
<td>0.0438</td>
</tr>
<tr>
<td>Pain/Discomfort</td>
<td>87±17</td>
<td>84±21</td>
<td>0.0024</td>
</tr>
<tr>
<td>Pulmonary function</td>
<td>88±14</td>
<td>89±15</td>
<td>0.0117</td>
</tr>
<tr>
<td>Transfer</td>
<td>85±22</td>
<td>88±18</td>
<td>0.1971</td>
</tr>
<tr>
<td>Physical function</td>
<td>87±17</td>
<td>89±14</td>
<td>0.0006</td>
</tr>
<tr>
<td>Daily living</td>
<td>70±26</td>
<td>72±24</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fatigue/Energy</td>
<td>73±23</td>
<td>73±18</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Emotion</td>
<td>86±13</td>
<td>86±14</td>
<td>0.0022</td>
</tr>
<tr>
<td>Parent burden</td>
<td>69±15</td>
<td>72±15</td>
<td>0.0012</td>
</tr>
<tr>
<td>Financial burden</td>
<td>59±28</td>
<td>56±31</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>53±23</td>
<td>55±31</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HRQoL</td>
<td>82±12</td>
<td>81±10</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

\[ R^2 = 0.17746 \]  
\[ R^2 = 0.091844 \]
6MWD correlated with total score of EOSQ-24 in patients with EOS at both the 1\textsuperscript{st} and 2\textsuperscript{nd} test (N=49).

\[(R^2 = 0.1278, \ P = 0.0216) \quad \text{and} \quad (R^2 = 0.1088, \ P = 0.0329)\]

\[\Rightarrow\text{Serial growth-friendly interventions for EOS may not negatively affect function & QOL below their baseline preoperatively}\]