Assessment of Physical Activity and Fitness in Children

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Activity Promotion Lab
East Carolina University
Partner Organizations:

- President’s Council on Fitness, Sports and Nutrition
- AAHPERD
- CDC
- AAU
- The Cooper Institute [FitnessGram]
FitnessGram Test Items

- **Aerobic Capacity**--may select one option
  - PACER test
  - One-mile run/walk
  - Walk test (ages 13 or older)

- **Muscular Strength, Endurance, and Flexibility**
  - Abdominal strength and endurance (curl-up)
  - Trunk extensor strength and endurance (trunk lift)
  - Upper body strength and endurance (push-up, modified pull-up, flexed arm hang)

- **Flexibility** (back-saver, sit-and-reach, shoulder stretch.)

- **Body Composition**--may select one option
  - Percent body fat (calculated from triceps and calf skinfolds or an alternative measuring device)
  - Body mass index (calculated from height and weight)
Primary FitnessGram Assessments

Images courtesy of FitnessGram.
FitnessGram

State Adoptions
- California
- Texas
- Georgia
- Delaware
- North Carolina

Large District Adoptions
- New York City
- Miami-Dade
- Indianapolis
Appropriate Uses of FitnessGram

- Provide students, teachers, and parents with personal information on current levels of health-related fitness.
  - Use the information to design programs of fitness development.
- Institutional testing to allow tracking of group data (for curriculum development).
- Help students track fitness results over time.
- Document use of FitnessGram as part of a PE curriculum.
Inappropriate Uses of FitnessGram

- Scores on fitness tests should not be used to grade students in PE.
- Students fitness test scores should not be used for teaching evaluations.
- Students fitness test scores should not be used to evaluate the overall quality of the PE program.
Aerobic Capacity

- Output is expressed as $\text{VO}_2\text{max}$ in $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. 
Aerobic Capacity Vignette
Progressive Aerobic Cardiovascular Endurance Run
PACER

- Starts out slowly and gets faster each minute.
- Pace is controlled by CD and can be set to music.
- Students run back and forth across 20-m distance until they cannot maintain pace.
  - less fit students end the test first
  - 15-m distance
- Score is number of laps competed.
- More enjoyable alternative to mile run.
Objective: Run as long as possible back and forth across 20-m at pace specified by CD.

Equipment Needs: flat surface at least 20 m long, PACER CD, CD player, measuring tape, marker cones.

Allow practice sessions.
PACER Video
Criterion-referenced Standards

- Provide feedback on how fit a child needs to be for health.

- Based on number of laps and other variables, \( VO_{2\text{max}} \) is estimated.

- Estimated \( VO_{2\text{max}} \) is then compared to the criterion-referenced standard and participants are categorized:
  - Healthy Fitness Zone
  - Needs Improvement – Some Risk
  - Needs Improvement – Higher Risk
Revision of Health Related Standards

Aerobic Capacity and Body Composition

American Journal of Preventive Medicine
October 2011 supplement

Morrow JR, et al. [1]
Approach to Setting Standards

- Based on nationally representative data (from NHANES).
- LMS curves were used to account for growth and development.
- ROC curves were used to determine optimal cut-points that detected risk for metabolic syndrome.
Estimated \( VO_2^{\text{max}} \) in Boys

Nationally representative sample from NHANES.
Estimated VO$_{2\text{max}}$ in Girls

Nationally representative sample from NHANES.
Smoothed LMS curves for various percentiles of estimated VO2max (mL/kg/min) for Boys

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ROC Curve to Determine Optimal Cut-Score
Aerobic Capacity (VO$_{2\text{max}}$) Males vs. Females

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Joe Jogger
Grade: 5, Age: 12
FITNESSGRAM Elementary School
Instructor(s): Bostick, Sue

Date          Height          Weight
Current: 01/16/2010  5'11"      123 lbs
Past: 05/05/2009   4'11"       120 lbs

MESSAGES

You should work to improve your aerobic capacity. Try to do more physical activity (60 minutes every day). Play active games, sports, or other activities that make you breathe hard. Good aerobic capacity is important in preventing health problems.

To improve your upper-body strength, be sure that your strength activities include modified push-ups, push-ups, and climbing activities. You may need to do more arm exercises.

Your flexibility is in the Healthy Fitness Zone. To maintain your fitness, stretch slowly 3 or 4 days each week, holding the stretch 20-30 seconds. Don’t forget that you need to stretch all areas of the body.

Your abdominal and trunk strength are both in the Healthy Fitness Zone. To maintain your fitness, be sure that your strength-training activities include exercise for each of these areas. Abdominal and trunk exercises should be done at least 3 to 5 days each week.

Joe, your body composition score needs improvement. If it stays at this level you will have a much greater chance of future health problems. You also report low levels of physical activity and this may lead to health problems. To improve, do the following:
- Try to get more activity (at least 60 minutes every day).
- Reduce time spent watching TV or playing video games.
- Eat a healthy diet including fresh fruits and vegetables.
- Reduce your calories from foods with solid fats and added sugars.

Improving your body composition score will improve your health and may help to increase fitness scores.

Healthy Fitness Zone for 12-year-olds:
- Aerobic Capacity: ≥ 2.40
- Curl-Up: ≥ 18 repetitions
- Trunk Lift: 3-12 inches
- Push-Up: ≥ 20 repetitions
- Back-Saver Sit and Reach: At least 8 inches on R & L
- Percent Body Fat: 8% - 23%

To be healthy and fit it is important to do some physical activity almost every day. Aerobic exercise is good for your heart and body composition. Strength and flexibility exercises are good for your muscles and joints.

Good job! You are doing some aerobic activity and strength and flexibility exercises. Additional vigorous aerobic activity would help to promote higher levels of fitness.

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Measurement of \( \text{VO}_2 \text{max} \)
Mission of FitnessGram

- Promote lifelong *physical activity* among youth.
- Developing fitness is important in physical education, but the broader context is providing children with the:
  - Knowledge
  - Attitudes
  - Skills
to be active for a lifetime.
Physical Activity

Any behavior involving bodily movement that raises energy expenditure above normal resting levels.

Two components:
- Behavior
- Movement

It is almost always more difficult to measure human behavior (physical activity) than an outcome variable.
Why Measure Physical Activity?

- Examine relationship between PA and other health-related variables.
- Determine whether an intervention has an effect on PA.
- Document prevalence of PA or inactivity.
Physical Activity Measurement

- Physical Activity Diary
- Recall Questionnaire
- Heart Rate Monitors
- Doubly Labeled Water
- Direct Observation
- Calorimetry
- Pedometers
- Accelerometers
Percent Meeting Physical Activity Recommendations

- Youth-YRBS: 67%
- Youth-Act Monitor: 7%
- Adults-BRFSS: 46%
- Adults-NHIS: 30%
- Adults-Act Monitor: 3.5%
Accelerometry

- Objective
- Measures movement directly
- Little evidence of reactivity
- Can assess intensity of physical activity
- Can assess total activity accumulated
- Can assess patterns of physical activity
Accelerometry Limitations

- Cannot assess movement associated with non-ambulatory activities (unless worn on the wrist).
- Cannot differentiate between level and uphill walking (yet).
- Cannot detect additional EE from lifting or carrying loads.
- Require significant time for cleaning and analyzing data.
- Relatively expensive.
Accelerometers

- ActiGraph
- Actical
- Acti’Trainer
How does accelerometry work?

- Accelerometers measure body movement in terms of acceleration.
  - Acceleration is related to intensity of physical activity
- Convert mechanical force or movement into an electrical signal.
- Measured by piezoelectric element plus a seismic mass.
  - The tension or bending of the beam upon acceleration generates a proportional electric signal.
- Can measure movement in 1 to 3 planes.
- Data are stored for later download and analysis.
Accelerometer Output

Activity Counts
- Generated based on sampling frequency
- Range of 1-100 Hz

Usually summed over user-defined epoch
- Often 1 min has been used
Other Accelerometer Output

- Depends on specific accelerometer
  - Steps
  - Estimated energy expenditure
  - Pattern of activity counts over time
  - Average counts/min
  - Time spent within given count criteria
    - Sedentary, light, moderate, vigorous.
## Sample Accelerometer Output

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</tr>
<tr>
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<td>5898</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>1757</td>
</tr>
<tr>
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</tr>
<tr>
<td>9/8/04 5:35 PM</td>
<td>118</td>
</tr>
<tr>
<td>9/8/04 5:36 PM</td>
<td>546</td>
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Sample ActiGraph Output

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<tr>
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<tbody>
<tr>
<td>Start Time: 04:00:00</td>
</tr>
<tr>
<td>Start Date: 05/31/2005</td>
</tr>
<tr>
<td>Cycle Period: 00:01:00</td>
</tr>
<tr>
<td>Download Time: 16:32:12</td>
</tr>
<tr>
<td>Download Date: 06/16/2005</td>
</tr>
<tr>
<td>Current Memory Address: 32768</td>
</tr>
<tr>
<td>Battery Life Remaining: 1257 hours Mode = 3</td>
</tr>
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</table>

<table>
<thead>
<tr>
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<th>Activity</th>
<th>Date/Time</th>
<th>Activity</th>
<th>Date/Time</th>
<th>Activity</th>
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<td>6/3/05 9:55 AM</td>
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<tr>
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<td>1</td>
<td>6/3/05 9:56 AM</td>
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<td></td>
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<tr>
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<td>6/2/05 10:00 AM</td>
<td>14</td>
<td>6/3/05 10:00 AM</td>
<td>123</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activity counts

Clock time

Counts

Vigorous

Moderate
Accelerometer Issues

- Selection of accelerometer
- Sampling interval or epoch length
- How many days?
- How long to monitor for a valid day?
- Spurious and missing data
- Calibration of accelerometer output
- Compliance
- New uses
Selection of Accelerometer

- **Uniaxial (ActiGraph GT1M)**
  - Measures acceleration in vertical plane.

- **Triaxial (ActiGraph GT3x)**
  - Measures accelerations in vertical, anterior-posterior, and mediolateral planes

- **Omni-directional (Actical)**
  - Measures best in one plane, but also measures in second plane.

Different models seem to provide comparable estimates of free-living physical activity

- Slight improvement in some validity estimates with > 1 axis
- Output of triaxial and uniaxial are highly correlated

Consider:

- Cost, practicality, reliability and validity
Sampling Interval or Epoch Length

- Accelerometer signal is integrated over a user-defined time interval or epoch.
- The signal is summed and stored.
- Traditionally, most studies set epoch at 1 minute.
- A 1-min epoch is probably too long for children.
Children’s Physical Activity Patterns

Recommended children and adolescents participate in ≥ 1 hour of physical activity per day.

Most of the 1 hour or more should be of moderate to vigorous intensity.

Can be accumulated throughout the day.

Measurement instrument must be sensitive to children’s activity patterns.
Children’s Physical Activity Patterns

Characterized by:

- Short bursts of intense activity
- Varying intervals of low and moderate intensity activity

Bailey et al. (1995)

- Observational study on 6-10 year old children
- Recorded child’s physical activity behavior (i.e., posture and intensity) every 3 seconds for 24 minutes
Children’s Physical Activity Patterns

Intensity
- High intensity: 3.1% of time
- Moderate intensity: 19.7% of time
- Low intensity: 77.1% of time

Median Duration
- High intensity: 3 sec
- Moderate intensity: 6 sec
- Low intensity: 6 sec
- 95% of activities lasted < 15 sec
- Just 0.1% of activities lasted for > 1 min

Bailey et al. (1995)
Children’s Physical Activity Patterns

- Intermittent in nature
- Short bursts of high intensity activities
- Varying intervals of low and moderate intensity activities
Children’s Physical Activity Patterns and Epoch Length

Because accelerometers sum activity counts over a user-defined epoch, short bursts of vigorous activity, which may generate high activity counts, may not be detected when activity counts are summed over longer epochs (such as 1-minute).
Effect of Sampling Interval on Objectively-measured Physical Activity in Pre-school Children

![Bar chart showing moderate-to-vigorous intensity activity across different epoch settings (1, 3, 5, 15, 30, 60 seconds).]

- Significant epoch effect ($p < .01$)
- Generally, minutes of activity differed between three smallest epochs (1-, 3-, 5-sec) and three largest epochs (15-, 30-, 60-sec) for MVPA.

Mahar et al. (2008)
Effect of Sampling Interval on Objectively-measured Physical Activity in Pre-school Children

Significant epoch effect ($\phi < .01$)

Minutes of activity differed between all epoch settings for vigorous intensity.

Mahar et al. (2008)
Assessing Physical Activity among Children with Accelerometers using Different Time Sampling Intervals and Placements

Nilsson et al. (2002)
Assessing Physical Activity among Children with Accelerometers using Different Time Sampling Intervals and Placements

Nilsson et al. (2002)
Impact of Sampling Interval on Prevalence of Meeting Physical Activity Recommendations

- NHANES 2003-2004 accelerometer data
- \( N = 6,329 \)
- \( n = 597 \) [6-11 yr old]
- \( n = 1,181 \) [12-19 yr old]
- Low percentage of children meeting public health recommendation for physical activity
- But epochs were set at 1-min intervals, which may underestimate MVPA in children
How Many Days of Monitoring?

Because physical activity varies from day-to-day, multiple days of monitoring are needed to provide a reliable indicator of habitual physical activity.
Intraclass Reliability Estimates for Multiple Days of Monitoring for MVPA

Trost et al. (2008)
**Recommended Days of Monitoring**

To achieve a reliability of .80:

<table>
<thead>
<tr>
<th>Grades</th>
<th>Mean Age ± Standard Deviation</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grades 1-3</td>
<td>7.2 ± 1.4</td>
<td>4.7</td>
</tr>
<tr>
<td>Grades 4-6</td>
<td>10.4 ± 1.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Grades 7-9</td>
<td>12.9 ± 0.9</td>
<td>8.3</td>
</tr>
<tr>
<td>Grades 10-12</td>
<td>15.8 ± 1.1</td>
<td>8.8</td>
</tr>
</tbody>
</table>

- **Children:** 4-5 days of monitoring.
- **Adolescents:** 8-9 days of monitoring.

7 days provides an estimate of reliability > .75 for children and adolescents.
How Long to Monitor for a Valid Day?

Various opinions:

- Troiano et al. (2008): 10 hours
- Anderson et al. (2005): 10 hours
- Eiberg et al. (2005): 8 hours
- Masse et al. (2005): 80/70 rule; wore accelerometer for at least 80% of a standard measurement day.
  - Standard measurement day = length of time 70% of sample wore accelerometer.
How Long to Monitor for a Valid Day?

- Probably population specific.
- 10 hours seems appropriate, but further research is needed.
- Requiring same criteria for weekdays and weekend days might not work with children.
  - Fewer hours might be monitored on weekends.
Spurious Data

Are they wearing the accelerometer?

- How many consecutive counts/min = 0 indicate accelerometer is not being worn?
  - 20 min (Esliger et al., 2006)
  - 60 min (Troiano et al., 2008)

- Must identify some number of consecutive zeros as behaviorally unlikely.
Missing Data

Visual inspection can determine obvious non-wear time.
Over 7 days, some participants will remove the accelerometer.

Approaches to handling missing accelerometer data:

- Use only participants with complete days.
- Imputation.
- Mean replacement.
Calibration of Accelerometer Output

Accelerometer activity counts:

- Dimensionless unit
- Depend on sensitivity specifications of individual accelerometers
Calibration of Accelerometer Output

- Activity counts are calibrated with energy expenditure (VO$_2$) to give biological meaning to the output.
  - This results in cut-scores associated with categories of activity intensity.
  - We can then calculate time spent in different intensities (e.g., moderate, vigorous, MVPA).
Calibration of Accelerometer Output

Lack of agreement on activity counts available is a major issue in accelerometer research.
Compliance

Few studies have examined different strategies to promote compliance.

Some Thoughts:

- Provide explicit instructions on wearing accelerometer:
  - when, where on body, etc.

- Use a log sheet to have participants document:
  - Time on
  - Time off
  - Monitor off times (sleep, swim, contact sports)

- Follow-up phone calls or text messages.
- Have participants call research phone number and leave message that they put monitor on.
Compliance

- Provide participants with a list of FAQs.
- Provide written reminders (e.g., stickers) to be displayed on:
  - Bedroom dresser
  - Bathroom mirror
  - Refrigerator
  - Exit door to house
<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
<th>Day 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wednesday</td>
<td>Thursday</td>
<td>Friday</td>
<td>Saturday</td>
<td>Sunday</td>
<td>Monday</td>
<td>Tuesday</td>
<td>Wednesday</td>
</tr>
<tr>
<td>Time On</td>
<td>Time On</td>
<td>Time On</td>
<td>Time On</td>
<td>Time On</td>
<td>Time On</td>
<td>Time On</td>
<td>Time On</td>
</tr>
</tbody>
</table>

Please call this number when you put the monitor on each day and leave your name: 513-8025

<table>
<thead>
<tr>
<th>Time Off</th>
<th>Time Off</th>
<th>Time Off</th>
<th>Time Off</th>
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<th>Time Off</th>
<th>Time Off</th>
</tr>
</thead>
</table>

Did you remove the activity monitor during the day anytime when you did physical activity?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

If you did remove the activity monitor, what time did you remove it?

If you did remove the activity monitor, for how many minutes were you not wearing it?
Compliance

- Show participants example of output to let them know you can tell when they are not wearing accelerometer.
  - Not to be coercive
  - Education about accelerometer output

- Provide incentives.
  - Maybe contingent upon compliance
New Uses of Accelerometers

Use of accelerometers by practitioners (e.g., personal trainers) to assess physical activity profiles and identify to clients when they might fit physical activity into their day.
Summary

- **Accelerometer Selection**: not enough evidence to suggest a superior model.
  - Ease of use
  - Reliability
  - Technical support

- **Sampling Interval**: more work is needed, but 1-minute epochs are probably too long for children.
Summary

How Many Days? A 7-day monitoring period may be a reasonable balance between accuracy and feasibility.

How Long is Need for a Valid Day? 10 hours seems appropriate for weekdays; maybe slightly shorter for weekend days.

Spurious Data: Need to consider consecutive zeros [60 minutes of consecutive zeros is a conservative estimate of non-wear time].
Summary

**Missing Data:** Mean replacement by either all other days or other similar days (i.e., weekday, weekend) provides good estimates.

**Calibration of Accelerometer Output:** Very interesting area of research that is still being developed.

**Compliance:** Use multiple strategies to promote compliance with wearing procedures.
Summary

New Approaches: We’ve only been working with accelerometers for ~ 30 years. A lot of work is still to be done and a lot of new ideas are still to emerge.
Thank you!