# Youth Energy Expenditure Workshop

April 19-20, 2012, Atlanta, GA
National Collaboration on Childhood Obesity Research (NCCOR)

## Workshop Overview

NCCOR's overall mission is to improve the efficiency, effectiveness, and application of childhood obesity research and to halt the current childhood obesity epidemic through enhanced coordination and collaboration. High-quality research tools are essential to achieving several of NCCOR's goals:

- Identify, design, and evaluate practical and sustainable interventions, especially in high-risk populations and communities.
- Increase and improve national, state, and local surveillance of childhood obesity.
- Improve the ability of childhood obesity researchers and program evaluators to conduct research and program evaluation.

Efforts to reduce childhood obesity must emphasize healthy eating and sufficient physical activity. In the physical activity arena, there is an ongoing need to convert self-reported or observed time spent in specific activities, such as playing soccer, into a common measure, such as Calories used per kilogram (kg) of body weight or metabolic equivalents (METs, defined below). Such common units are vital for comparing the effects of interventions targeting different kinds of physical activity and for research on the costs and benefits of energy expenditure (EE). The Adult Compendium of Physical Activities, first published in 1993, provides such information about adults and has had a tremendous impact on physical activity research and education. Enhancing an existing compendium of youth physical activities, published in 2008, to create a similarly comprehensive resource on children and adolescents is worthwhile, but investigators face a range of scientific and technical challenges in accomplishing this task.

The idea of holding a workshop to discuss methods and measurement of youth energy expenditure was first discussed at an NCCOR Member Meeting in January 2011 and formally presented to the Members in Fall 2011. Following NCCOR approval of the concept, a small working group led by Janet Fulton (Division of Nutrition, Physical Activity, and Obesity, Centers for Disease Control and Prevention) and David Berrigan (Applied Research Program, National Cancer Institute) was charged with planning the workshop. The working group played an integral role in formulating the goals of and planning the meeting. Its members were:

- Barbara Ainsworth (Arizona State University)
- Bob McMurray (University of North Carolina)
- Russell Pate (University of South Carolina)
- Karin Pfeiffer (Michigan State University)
- Stewart Trost (Oregon State University)

The meeting took place in Atlanta on April 19 and 20, 2012. Its goals were to:

- Discuss and plan for an updated, reformatted, and accessible version of the Youth Compendium of Physical Activities;

- Achieve consensus on a course of action to improve energy expenditure estimates for youth; and
- Develop a publication plan and timeline for a scientific paper(s) from the Workshop.

## SETTING THE CONTEXT: Need for an Updated Physical Activity Compendium for Youth: Benefits and Challenges

Dr. Russell Pate (University of South Carolina) provided essential context for the workshop. An enhanced compendium of youth physical activities would substantially improve our ability to conduct surveillance and research. Developing such a resource is challenging in several respects, however:

- *Developmental issues.* Resting metabolic rate (RMR) and the rate of EE decline significantly with age as children grow and develop. The rate of EE also declines with improvements in physical activity skills. These changes must be factored into youth EE estimates.
- *Variability in intensity.* The volitional effort and intensity children and youth apply to physical activity varies tremendously with age and type of activity. This has major implications for how activities are defined (e.g., young children playing with a basketball in the family driveway vs. high school varsity basketball).
- *Selection and administration of criterion measures.* A number of methods can be used to measure EE, including accelerometry, indirect calorimetry, and direct calorimetry. Decisions are needed about which methods are most feasible and scientifically desirable.
- *Logistics.* A process for developing an enhanced compendium will need to be established. Will it rely on systematic, funded studies or voluntary contributions of data? If the latter, what standards will be applied to data contributions?

## SESSION 1: History and Use of Adult and Youth Compendia: Overview and Lessons Learned

In Session 1, presenters provided some historical background by describing the development of and lessons learned from the Adult Compendium of Physical Activities and the 2008 youth compendium of physical activities:

- Overview of Compendium for Adults (Barbara Ainsworth, Arizona State University)
- Lessons Learned from the Adult Compendium (Steve Herrmann, University of Kansas Medical Center)
- Overview and Lessons Learned from the Youth Compendium (Kate Ridley, Flinders University, Adelaide, South Australia)

### Overview of Compendium for Adults

The Adult Compendium of Physical Activities began in 1987 under a grant from the National Heart, Lung, and Blood Institute. The original goal was to develop a comprehensive list of physical activities and associated metabolic equivalents (METs, or multiples of the average resting EE for a healthy, normal weight adult male; see page 7 for additional background on METs) as an aid to coding physical activity questionnaires in epidemiologic research. The Compendium was not intended for individual-level EE calculations.

William Haskell conceptualized the compendium and developed the prototype. Initially, the coding scheme for categorizing each activity had 7 digits; this was later reduced to 5 digits that categorized each activity by situation (e.g., self-care, sports), intensity, and specific activity. The development team used published literature and ongoing studies to compile information about activities and intensities. METs were assigned based on measured values. For those activities that had not been measured, values from similar activities that had been measured were assigned. Version 1 of the Compendium was published in 1993, with 19 categories of activities.

The Compendium has been updated twice, in 2000 and 2011. The new versions have allowed the authors to amend values to reflect recent research and to delete and add activities (e.g., mine sweeping has been deleted and aerobic dance has been added). The 2000 version was widely distributed and applications have proliferated, from use in surveillance studies to consumer education in MyPyramid and on cereal boxes. A Tracking Guide was developed in 2000 and updated in 2011. It identifies new categories and updated values so that users can compare versions of the Compendium. More than 60% of the activities in the 2011 Compendium have measured values, and it contains references for every measured activity.

***Implications for Developing Energy Expenditure Estimates for Youth***

- Developing a comprehensive, accurate set of standard energy expenditure values will take time, effort, and funding.
- It may be desirable to develop products that apply to different audiences, such as products for researchers and practitioners.
- It is very important to have a "champion" to advocate for and lead the effort and to develop a succession plan so that strong leadership will continue. This may take a substantial investment of time.

## Lessons Learned from the Adult Compendium

A website (http://sites.google.com/site/compendiumofphysicalactivities/home) to accompany the Adult Compendium has been developed. The website contains downloadable information (e.g., the 2011 Compendium, Tracking Guide, a table of new activities, references), helpful resources such as conversions and corrected METs that adjust for RMR, and referrals to other resources such as Exercise is Medicine and IPAQ translation instructions. The inclusion of references to support the values provided in the Compendium is an important component of this resource.

Recent updates include French, Italian, Japanese, and Spanish translations and a "new activities" page to which website users can submit their research (this page is not an official part of the Compendium but still useful as a repository of studies in this topic area). The website is interactive to some degree in that users can send emails to the "Contact Us" page. Future interactive possibilities include adding a chat/comment forum and Twitter and Facebook capability. Thinking through the best ways to share the website and its resources is a challenge for the future.

The website has seen some commercial applications in that other websites include links to the Compendium website and several diet and physical activity mobile apps have been developed that use data from the website. Traffic to the site has been fairly steady over the past year, with about 800 visitors per week and a total of about 55,000 visitors.

***Implications for Developing Energy Expenditure Estimates for Youth***

- It is important to proactively consider whether a Youth Compendium companion website would be a useful way to promote the resource and if so, how to support its development and sustainability over time.
- If the decision is made to pursue a companion website, it is very important to have a "champion" to advocate for and lead the effort and to develop a succession plan so that strong leadership will continue. This may take a substantial investment of time.
- It is important to have someone on the team who is familiar with social media and technological advances in data sharing.

## Overview and Lessons Learned from the Youth Compendium

The Youth Compendium of Energy Expenditures was originally developed as part of a larger PhD project, "Development and Validation of the Multimedia Activity Recall for Children and Adolescents (MARCA)." The Compendium was published separately in 2008 in response to requests from researchers seeking child-specific data to score self-report questionnaires and to supplement accelerometry data. Like the Adult Compendium, it more accurately estimates EE at a group level, rather than at an individual level.

A first step in compiling the Compendium was to conduct a literature search to find studies that measured energy costs of physical activities in children ages 6 to 18 years. Data on 56 activities were found. For activities with no child-specific data, four existing techniques for assigning EE values to children were compared. Analyses indicated that using adult METs was the most accurate assignment technique. Because the MET cost of walking and running is significantly influenced by age, prediction equations based on age and speed were used to estimate these values instead of using adult METs. The activities were assigned intensity values using published data and a reasonable, but arbitrary, weighting strategy.

The final list of 244 activities included in the Compendium was selected from the Adult Compendium, activity lists within physical activity questionnaires, and the MARCA project.

***Implications for Developing Energy Expenditure Estimates for Youth***

- The current Youth Compendium is useful but it is hampered by limited data and values based on studies with old data, adult data, or small sample sizes. It is a work in progress.
- Additional research is needed on the appropriateness of using universal MET values for standardizing EE (is correcting for children's higher RMR enough?). This research will need to consider appropriate age range (is age 6 to 18 years too wide?) and the variable nature of children's activities (data on activities involving mostly running are limited).
- In collecting new data to enhance the Compendium, decisions will be needed about:
    - Developing standardized protocols and reporting guidelines
    - Targeting areas of particular need (e.g., sports that involve intermittent movement or activities involving multiple types of movement conducted simultaneously, such as walking and texting)
    - Determining what RMR to use – measured or estimated
    - Determining how to report walking and running MET values
- Design issues also will need to be considered, including:

- Noting whether EE estimates for activities use directly measured or estimated values
- Providing information that helps users judge the quality of the data (e.g., providing year when data were measured; establishing a critical appraisal system based on sample size, generalizability of sample, year published)
- Considering eliminating light/moderate/hard values but including some measure of intensity or variability
- Mapping youth EE codes against other coding systems (e.g., national time-use surveys)

### Small Group Discussions

Workshop participants broke into small groups to discuss key issues in reformatting and updating the Compendium and ways to make the Compendium publicly accessible:

- Consider developing two versions of the youth compendium, including a less detailed and less technical version for practitioners and a more detailed and technical version for researchers. The less detailed version could be completed fairly quickly. Users of this version might include physical education teachers, youth program directors, and after-school programs.
- Consider appending the youth compendium to the Adult Compendium rather than developing it as a separate document. One way to do this might be to add characters to the adult codes to indicate child-specific data.
- Create and test an internationally available website for the youth data. A plan for managing and sustaining the website will be necessary.
- Consider ways to gather all available youth EE data, especially data since 2005. Consider whether it would be useful to gather international data as part of this effort.
- Determine the best ways to gather the data. Possibilities include conducting a literature review or hosting a conference at which investigators could present unpublished data. A publication or journal supplement could be developed as a product and this possibility might be a good incentive for researchers to participate.
- Include EE values for special populations, such as children with disabilities.

### SESSION 2: Indirect Calorimetry and Monitoring Devices to Measure EE

In Session 2, presenters discussed several issues that are central to measuring and quantifying EE in youth and further developing a youth compendium of physical activities. These issues include factors that influence EE in youth, potential methods for measuring EE, and metrics for expressing EE:

- Direct Measurement of EE in Youth – History and Present State of the Art (Bob McMurray, University of North Carolina)
- Estimation of EE with Metabolic Chambers (Nancy Butte, Baylor College of Medicine)
- Estimation of EE with Mechanical Devices (Stewart Trost, Oregon State University)

## Direct Measurement of EE in Youth – History and Present State of the Art

The key challenge in measuring EE in children is that children are not small adults. They differ in many ways, including hormonal levels, metabolic responses, muscle mass, cardiovascular and respiratory characteristics, and physical dimensions. Various factors also affect their EE during physical activities, including resting EE, mass-speed imbalance, muscular efficiency, stride frequency, gait kinematics, body composition, ventilation efficiency, and substrate utilization. Studies measuring metabolic rate have been conducted since the 1930s. Some features of the equipment used have changed while others have stayed the same. The weight of the equipment continues to be a challenge in studies involving children.

A second important issue in measuring EE is defining an appropriate metric. In adults, the MET (defined as 3.5 ml/kg/min or 1.0 kcal/kg/h) is used, but the resting metabolic rates upon which METs are based vary widely in children and youth of various ages.

A third issue is determining which physical characteristics (i.e., age, body mass index [BMI], body fat, height, fat free mass, puberty, skin fold) of children and youth become important when examining EE during activity. Many are related so it is difficult to know which might be limiting factors in determining EE.

The Youth Compendium currently provides metabolic data for 54 physical activities in children and youth, but these data have gaps. Children do many more than 54 activities and no energy expenditure data currently exist for these other activities. Very young children are not represented in the data on the 54 activities. Not all studies report age, pubertal status, or RMR, or consider the sex of the child. The studies are inconsistent in their approach to tabulating METs and they do not take into account the sporadic way in which children are active.

### *Implications for Developing Energy Expenditure Estimates for Youth*

- Considerable progress has been made in measuring EE in children but a number of significant gaps in knowledge remain.
- Considerable additional work will be necessary to create a comprehensive Youth Compendium. Decisions will need to be made about issues such as defining an appropriate metric, determining which physical characteristics to include in EE measurements, and accounting for the myriad factors that distinguish children's physical activity from that of adults.

**What is a MET?**

A person must expend energy to do physical activity. A metabolic equivalent, or MET, is a way to describe the energy cost of various physical activities. METs are expressed as multiples of resting metabolic rate (RMR). For example, 1 MET is the rate of energy expenditure at rest. A 4 MET activity expends 4 times the amount of energy used by the body at rest.

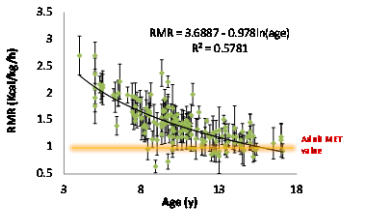
**How were METS developed?**

An 1890 text began the process that led to METs by describing the resting oxygen consumption ($VO_2$) of one 40 year-old man who weighed 70 kg (about 154 lbs) (Howley, 2000). In 1936, D.B. Dill first introduced the term MET and described the concept of different intensities of activity as multiples of basal metabolic rate (Dill, 1936). Two decades later, Balke popularized the idea of using METs to express physiologic and metabolic response to exercise in quantitative terms (Balke, 1960). Today, based on the original 1890 data, 1 MET, or resting energy expenditure, is commonly defined as equal to an oxygen uptake of 3.5 milliliters per kilogram of body weight per minute (3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$). A MET also can be expressed as 1 kilocalorie per kilogram of body weight per hour (1 $kcal \cdot kg^{-1} \cdot h^{-1}$).

**Are METs an accurate metric for everyone?**

No. A recent study measured RMR in a sample of nearly 800 healthy adult men and women of various body weights, and found that average $VO_2$ and energy cost of rest were significantly lower than the accepted 1 MET value. Body composition differences accounted for 62% of the variance in RMR and age accounted for only 14% (Byrne et al., 2005). It is also well-established that RMR in children declines with age, as shown in the Figure (McMurray RG).

Resting Metabolic Rates of Children 4-17 y of age




Each data point represents a mean & SD for one of 79 studies of children

Sources: **Balke B.** The effect of physical exercise on the metabolic potential, a crucial measure of physical fitness. *Exercise and Fitness*. Chicago: The Athletic Institute, 1960; **Byrne NM et al.** Metabolic equivalent: One size does not fit all. *J Appl Physiol* 2005;99(3):1112–9; **Dill DB.** The economy of muscular exercise. *Physiological Reviews* 1936;16:263-91; **Howley ET.** You asked for it: Question authority. *ACSM Health Fitness* 2000;4:6-8; **McMurray**, unpublished compilation of data from 79 studies; contact Dr. McMurray (exphys@live.unc.edu) for references for each study.

## Estimation of EE with Metabolic Chambers

One key tool to measure youth energy expenditure is metabolic chambers. The Children's Nutrition Research Center (CNRC) at Baylor University has two large and two small respiration calorimetry chambers that can provide minute-to-minute EE data, which helps in studying the sporadic nature of children's activity. CNRC has used these chambers to conduct studies with 184 preschoolers and 1,629 children and youth ages 5 to 18.

These studies have focused on accounting for age-specific declines in basal metabolic rate (BMR) to develop useful compilations of EE data. They also have examined effects of obesity and age-related changes in EE in addition to BMR, such as changes potentially associated with efficiency. The results of these studies make it clear that adjustment for a single BMR for all youth age groups would result

in significant bias in estimated EE, especially for more vigorous activities such as jogging. Similarly, ignoring weight status would substantially underestimate EE across a wide range of age categories.

A second major problem involves the estimation of EE for activities that cannot be performed in the respirometry chambers, such as team sports or free play in outdoor settings. In a new study, called **li'l cal**, the CNRC investigators are evaluating the utility of metabolic chambers for calibrating heart rate and accelerometer measurements as tools to estimate EE in free-living children. These efforts are promising, but the protocol for this approach is not yet optimal.

***Implications for Developing Energy Expenditure Estimates for Youth***

- Room calorimetry can be used to measure EE of activities in children. It has advantages and disadvantages.
- Advantages:
    - No need to wear equipment
    - Can assess sedentary and low active locomotor activities
    - It can establish the EE:heart rate and EE:accelerometer counts relationships for other activities if used in conjunction with heart rate and accelerometer monitors
- Disadvantages:
    - Activities limited to confined spaces
    - Safety concerns for very young children
- Next steps should include assessing gaps in knowledge and obtaining funding for EE measurements, quality control, and statistical analysis.

## Estimation of EE with Mechanical Devices

Some investigators have queried whether mechanical devices, such as accelerometers, can be used to estimate EE values for use in a youth compendium. Accelerometers are valuable for generating cut points to distinguish levels of intensity in physical activity on a population basis, but they are not as accurate for developing point estimates of energy costs for individuals.

Children's height, age, and economy of movement all affect accelerometer counts and prediction equations. At present there appears to be rapid progress in the use of accelerometers, inclinometers, and/or heart rate monitors to estimate EE. Achieving device-based estimates of youth EE is a reasonable goal in the next few years, but the field is not quite at that stage yet.

***Implications for Developing Energy Expenditure Estimates for Youth***

- The use of EE values predicted from wearable motion sensors is worth continued discussion but direct measurements of EE should take priority over indirect measures derived from wearable motion sensors. This conclusion is based on the observation made by several participants that accuracy is still a limitation for estimates of EE from wearable sensors.
- Next steps should include continued development of algorithms and support for research on technology-based physical activity EE assessment.

### Full Group Discussion

Workshop participants reflected on the preceding presentations and discussed which EE method(s) would be most feasible to incorporate into the Youth Compendium and next steps in carrying out this task. A number of issues arose in the discussion:

- Age-related variability in RMR is perceived to be a problem but it does not need to be a major source of error. Adjustments for resting EE (either estimated or measured) could be applied to youth compendium values to eliminate or minimize age-related variability as a significant source of error.
- Considerable discussion focused on normalizing the data so that a single MET value can be used across the data and across ages. This may work for sedentary and light activities but is problematic for moderate and vigorous activities. More analysis is needed to determine the best approach to this normalization.
- Is it possible to take the data from available literature and fold it into the existing Youth Compendium or must the data be developed from scratch? If it were possible to extract raw data from studies, then it might be possible to develop a table or calculator to transform the raw data into desired values for the compendium.
- Further work is needed to estimate energy expenditure during team sports and other activities. Wearing portable devices may have an effect on the pattern of play. Video imaging of youth engaged in actual games combined with respirometry chamber-based measurements could fill gaps in data for activities that cannot occur in chambers.

Participants agreed that several key problems need to be resolved to determine the best metric to represent EE:

- How to adjust for age-related variability
- How to define a common metric and how should it be expressed for different users (i.e., researchers, practitioners). This metric will need to be as reliable as possible. EE is the measure of main interest. An expression of EE is needed that will be most valuable for the uses to which the Youth Compendium will be put.

## SESSION 3: Challenges and Opportunities for EE Measurement

In Session 3, presenters focused on key factors that affect the accuracy of EE estimates:

- Inter-individual Variation in EE (Karin Pfeiffer, Michigan State University)
- Training and Biomechanical Efficiency in Estimating EE (Don Morgan, Middle Tennessee State University)

### Inter-individual Variation in EE

Variation is an important concept to consider in estimating EE in youth because the amount of energy required to perform physical activities changes with age and pubertal status. Certain age periods may show greater variability than others, resulting in greater potential for error in estimating EE. In addition, variation may affect prediction of response for a given dose of physical activity.

Data from two samples – the Trial of Activity for Adolescent Girls [TAAG] and the Longitudinal Validity of Accelerometry in Youth [LVAY] – provide some insights into the impact of variation. The data indicate that sedentary activities, such as resting or watching TV, have the most variability in EE. Ambulatory activities, such as walking and running, have the least variability, and lifestyle activities, such as sweeping floors or shooting basketballs, are intermediate. LVAY data indicate some sex differences but no clear pattern, and suggest that variability by age or maturity status depends on the activity.

***Implications for Developing Energy Expenditure Estimates for Youth***

- Variation can be incorporated into a youth compendium but it will be necessary to first determine whether and when it matters to EE estimates.
- Next steps should include further longitudinal examination of the effects of growth and maturation on variability in EE.

## Training and Biomechanical Efficiency in Estimating EE

It is well established that children have less locomotor economy (defined as the mass-related oxygen consumption required to sustain a submaximal walking or running speed) than do adults. In other words, children have a higher aerobic demand per unit of body mass than do adults. This disparity lessens as children become older.

A number of factors explain the higher metabolic costs of pediatric locomotion, including less efficient ventilation, faster stride rates, immature gait patterns, larger surface area to body mass ratio, decreased ability to store and recoil elastic energy in the legs, imbalance between body mass and muscle contraction speeds, and body mass/composition differences. Studies have looked at sex differences in locomotor economy in children, but results are equivocal. Training over the short-term appears to have no significant effect, but long-term training does appear to improve locomotor economy.

Various approaches can be used to control for body size when scaling the aerobic demands of walking and running. These methods, which include ratio scaling, allometric scaling, and size-independent cost scaling, each have advantages and disadvantages.

***Implications for Developing Energy Expenditure Estimates for Youth***

- The use of prediction equations incorporating age and speed to estimate walking and running $VO_2$ seems appropriate. The use of adult METs, along with child-specific RMR values, also seems appropriate.
- Next steps should include continued research on children and youth to identify the full range of active and sedentary pursuits that are relevant to youth, refine the energy cost values for activities currently listed in the youth compendium, and compare energy cost values found in the Youth Compendium with those obtained using existing and emerging activity monitoring devices.

## Small Group Discussions

Workshop participants broke into small groups to discuss ways to improve the accuracy of EE estimates from the Youth Compendium and next steps and timeline for this work. They also

discussed strengths and challenges of developing a repository of EE values (published and unpublished) for youth. The small groups made a number of suggestions in their reports to the overall group:

- In determining the best metric to use in reporting EE values, consider users (practitioners vs. researchers) and the desirability of normalizing the data to the greatest extent possible. Normalizing the data works better for sedentary and light activities than moderate or vigorous, but many of the activities in which children are engaged are sedentary or light. Many practitioners will not be concerned with the greater error associated with normalizing moderate or vigorous activities.
- Three approaches for expressing a metric are possible:
  - Express it as a ratio (EE/RMR)
  - Express it as a net value (EE – RMR = net EE adjusted for age of child)
  - Express it using allometric scaling, which adjusts for body size (e.g., $EE/kg^{-0.75}/min^{-1}$)
- Keep in mind the desired function of the youth compendium and potential users. For example, the Environmental Protection Agency (EPA) conducts research for agencies to use in developing regulations. EPA researchers may develop population-based simulations for air pollution using data from human activity diaries. Part of this exercise would involve estimating EE and ventilation rates. The youth compendium would be very helpful for this purpose.
- Plan on an effort with both short-term and long-term components. Over the short term, consider a conference at which people could present and discuss data. The product would be a supplement. Researchers could contribute these data to a repository that would be used over the long-term to improve the compendium.
- In gathering data on sample populations for the repository, it would be helpful to elaborate on the characteristics of the sample population (e.g., weight, height, fat free mass, measured and predicted RMR, age, sex, skill level) and the activity itself (e.g., intensity).
- Planning for a data repository must consider issues such as sponsorship, funding, sustainability, and usability by various audiences.

## SESSION 4: Interpolation and Estimation of EE

In Session 4, presenters discussed challenges in using adult EE data as a basis for estimating EE in youth:

- Estimation of EE Based on Adult Data (David Bassett, University of Tennessee)
- EE in Children and Adolescents: Perspectives from Growth and Maturation (Bob Malina, Tarleton State University)

### Estimation of EE Based on Adult Data

Using adult data to predict EE in children appears to provide a good "rough estimate," but it is preferable to collect measured EE on children rather than rely on adult data. The issue is what common metric that accounts for age and body size is best to use.

A MET is defined as equal to 3.5 ml/kg/min or 1.0 kcal.kg/hr. However, not everyone has a resting EE of 3.5 ml/kg/min. Children and adolescents have higher resting EEs and obese adults have lower resting EEs. As a result, several alternatives to METs have been proposed, including Measured METs (total EE/measured resting EE) and Corrected METs (total EE/estimated resting EE). The current Adult Compendium uses the standard definition of 3.5 because it is consistent with the definition used in the original version of the Compendium. In addition, Corrected METs have not been shown to be superior for normalizing the data in adults, but they have been shown to be superior in children and adolescents.

Two viable approaches exist for using adult data to estimate youth EE. The first is to adjust for age. The current Youth Compendium uses standard METs to compute age-adjusted metabolic equivalents (A-AME) for about 20 activities. A-AME = activity EE/resting EE for age group. Adjusting for the higher resting EE of children normalizes the data, allowing the Adult Compendium to be used to estimate EE in children and youth.

Another way to estimate EE using adult data is to adjust for body size, which increases as children grow older. Most physiological and biochemical processes, such as heart rate, respiration rate, and RMR, show scaling and are associated with the body size of the animal. Allometry is a mathematical expression of this relationship. Scaling submaximal $VO_2$ values for body size normalizes the data, avoiding the possibility that differences in $VO_2$ will appear to exist, when they are due solely to differences in body size. Different allometric exponents have been identified for the interspecific, intraspecific, and developmental allometry of metabolic rate. Great care will need to be taken to incorporate an allometric exponent into a revised compendium, as allometric associations between metabolism and body size are well known to differ for different developmental stages.

***Implications for Developing Energy Expenditure Estimates for Youth***

- Incorporating some method of scaling for body size into the youth compendium is feasible.
- There are several perspectives on the benefits of presenting the ratio of total EE to RMR (i.e., ratio methods for presenting energy expenditure, or total energy expenditure divided by RMR), with and without use of age-specific RMRs, versus presenting differences between total and RMR. A decision about final presentation of youth EE in an updated compendium can be delayed, as all the salient data will be abstracted from the existing compendium and new papers regardless.
- A second major issue involves whether or not to adjust for the allometric scaling of mass-specific metabolic rate. It may be possible to use a single allometric relationship, but this approach has some challenges. At the very least, it might not be equally useful across all age groups.
- Next steps should include comparing the ratio method and the allometric method for many physical activities to see which does a better job of normalizing the data and then deciding which is better based on theoretical and practical considerations.

## EE in Children and Adolescents: Perspectives from Growth and Maturation

Total energy expenditure (TEE) and its major components – resting energy expenditure (REE) and activity energy expenditure (AEE) are physiological measures. AEE depends on physical activity, a behavior that is influenced by the interactions of growth, maturation, and development.

Infancy and early childhood is a period of rapid brain growth, neuromuscular maturation, motor development, and dependence on adults. Obesity already is beginning in some preschool children, which has implications for their later motor development. Adiposity rebound, which occurs between early childhood and puberty, presages a period of rapid growth and development through late childhood and adolescence. Evidence suggests that the earlier the rebound, the greater the risk of later overweight and obesity. Children who are more active between ages 4 and 11 years also may have a later adiposity rebound and less fatness during early adolescence.

A number of studies have examined the variable effects of components of maturation and development on TEE, REE, and AEE. More recent studies also have examined these issues within the context of increases in obesity and declines in physical activity. Time trend data, for example, have demonstrated decreases between 1981 to 1997 in free/discretionary time, TV viewing time, and time in unstructured activities such as play. Physically active transport changed little during this period, and time in school/day care, in reading and studying at home, and in organized activities such as sports and hobbies increased. Other data examining changes in TEE and in average physical activity levels (PALs) in children ages 6 to 13 years between 1920 and 2011 show steady declines in energy expenditure. The same trend holds true for adolescents.

***Implications for Developing Energy Expenditure Estimates for Youth***

- Minimally, age and proper measurements of height and weight should be considered when developing estimates of EE for a youth compendium, but it is unclear whether including an indicator of maturity status is realistic.
- It is important to remember that children are not small adults and to recognize that adolescents are highly individual in the timing and tempo of sexual maturation and growth spurt. As a result, it will be difficult to build in these variables.

## Final Thoughts

Dr. Thomas Rowland (Baystate Children's Hospital) provided summary and concluding remarks. It is clear that a youth compendium is critically important in efforts to promote physical activity and exercise in children for health and reduce future risk factors for adult diseases. We need to provide guidelines for how much physical activity children need and we need to monitor it in the population. All of this requires accurate measurement.

The compendium must achieve a balance between precision and usefulness. The challenge is in deciding what we are willing to accept. That decision relates to the intended audience – the compendium will be woefully inadequate for some but extremely useful for others.

The next steps are to determine the best metric to use, update the current youth compendium with the most recent literature and the best metric, and define standard values that should be reported in the literature.

## CONCLUSION: Planning the Next Steps

In the final session of the workshop, participants planned next steps. To provide some context for this planning, David Berrigan summarized key areas of agreement and Janet Fulton laid out the main themes that emerged from the presentations and discussions.

## Key Areas of Agreement

1. The Youth Compendium is invaluable and we should invest in enhancing it.
2. Measured EE from metabolic chambers or with wearable respirometers is superior to estimated EE based on wearable devices or extrapolation from adults.
3. Play and team sports are significant challenges.
4. We should account for age-specific changes in RMR.
5. Careful consideration is required before incorporating an allometric adjustment into the EE values presented in the compendium
6. Accelerometer or other devices are not (quite) ready to measure energy expenditure for a youth compendium.
7. Estimates from adults may be better than nothing, but we should not include them in the compendium, users can go to the Adult Compendium.
8. We do not have a consensus about what metric to focus on for the Compendium.
9. We should address EE in obese/overweight and disabled youth.
10. There is a lot of interest in the creation and analysis of a repository of individual level data concerning youth energy expenditure.
11. There may be some additional data in the non-English literature, but not a huge amount.

## Main Themes

<u>Goal 1: Revise the Youth Compendium</u>

- Establish the audience(s)
- Clearly articulate the purpose of the compendium
- Determine how many physical activities should be included (all? most frequent?)
- Determine an acceptable level of precision (what is the minimal acceptable level of precision?)
- Develop a standard set of variables to report for this literature
- Establish website access
- Determine ownership and sustainability

<u>Goal 2: Research</u>

- Weigh simplicity vs. accuracy
- Determine common metric
- Decide on multiple covariates (age, maturation)
- Weigh measured vs. estimated values
- Decide what a MET is
- Plan conference and subsequent supplement
- Determine how to include special populations

<u>Short-term questions</u>

- What can we live with now?
- What do we know now?

<u>Short-term actions</u>

- Collect and update existing data
- Decide on a common metric

Long-term questions

- What do we not know?
- How do we discover this information?

Long-term actions

- Collect new data
- Develop optimal approaches and standardization procedures

## Next Steps

Workshop participants created seven teams, each of which was tasked with specific next steps in creating an enhanced Youth Compendium of Physical Activities.

***TEAM 1: Steering Committee***

*Team Members:* David Berrigan, Janet Fulton (team leads), Barb Ainsworth, Bob McMurray, Russ Pate, Karin Pfeiffer, Kate Ridley, Stewart Trost

*Charge:* Monitor and guide the project.

*Timeline:* Ongoing

***TEAM 2: Metrics***

*Team Members:* Bob McMurray (team lead), David Bassett, Nancy Butte, Kong Chen, Scott Crouter, Kristen Isaacs, Stewart Trost

*Charge:* Using data provided by workshop participants, evaluate different metrics for reporting youth energy expenditure to determine which is most accurate:

- Child METs
- Age-adjusted adult METs
- Gross EE: ml/kg/min
- Gross EE/$m^2$
- Gross EE/height in cm
- Net EE: gross EE – RMR
- Allometric, using Schofield equation

*Tasks:*

1. Develop an Excel spreadsheet for participants to use in submitting data so that all the data will be in the same format.
2. Evaluate the EE metrics.
3. Conduct regression analysis to examine the relative influence on EE of factors such as age, sex, pubertal status, obesity.
4. Publish results in a manuscript.

*Timeline:*

1. Develop Excel spreadsheet: 2 weeks (early May)
2. Receive and format all data: 2 months (end of June)

***TEAM 3: Youth Compendium Update***

*Team Members:* Kate Ridley (team leader), Ginny Frederick, Steve Herrmann

*Charge:* Update data in existing Youth Compendium (YC)

*Tasks:*

1. Investigate a suitable web-based site, such as Dropbox or Google Docs for the team and other workshop participants to share documents (David Berrigan and Janet Fulton to do).
2. On the papers included in the existing YC:
    a. Separate EE values in the YC that are based on measured child data versus those estimated from values in the Adult Compendium.
    b. Share inclusion criteria for papers included in original YC with workshop participants; discuss and decide which inclusion criteria to retain for updated YC.
    c. Categorize papers by age group (using age range of birth to 18 years, for now).
    d. Extract new information from the papers to calculate activity energy expenditure (AEE) values. Note whether RMR or Schofield equation used.
3. Conduct a search for new papers published since the publication of the YC (do literature search; ask workshop participants for titles/authors).

*Timeline:* Complete literature scoping search to determine extent of the task: End of May

***TEAM 4: Standards for Data Collection and Reporting***

*Team Members:* Barb Ainsworth (team leader), Carl Caspersen, Joan Dorn, Don Morgan, Russ Pate, Karin Pfeiffer

*Charge:* Develop proposed list of variables that should be included in data collection and reporting of youth energy expenditure values.

*Tasks:*

1. Compile a list of all possible variables and a list of minimum number of variables for consideration by workshop participants.
2. Develop proposals regarding methods and instruments to use in collecting data.
3. Circulate to workshop participants for their review and consideration.

*Timeline:* Distribute lists by end of April.

***TEAM 5: Youth Energy Expenditures Conference***

*Team Members:* Russ Pate (team leader), David Berrigan, Janet Fulton, Karin Pfeiffer, Kathy Watson

*Charge:* Plan a conference to explore youth energy expenditure measurement and development of a YEE data repository. Conference would provide a venue at which researchers could present unpublished data. Plan ways to inform the research community about efforts to update the YC.

*Tasks:*

1. Develop a list of upcoming conferences and meetings that could be used as venues to publicize the YC project (consider national meetings as well as regional meetings of national organizations).
2. Develop a small slide set that could be used in presentations at these meetings.
3. Begin planning/thinking about a YC conference.

*Timeline:*

1. Identify upcoming meetings and conferences and develop slide set: To be determined.

***TEAM 6: Common Data Repository for Youth Energy Expenditure Values***

*Team Members:* Steering Committee, others
*Charge:* Create web-based repository of individual-level data on youth energy expenditure.
*Tasks:* To be determined.
*Timeline:* Future, once initial tasks are underway/completed.

***TEAM 7: Publications***

*Team Members:* Bob Malina (team lead?), Tom Rowland, Stewart Trost, others
*Charge:* Coordinate development of manuscripts.
*Tasks:* To be determined.
*Timeline:* To be determined.

# *Appendix 1: List of Participants*

## Meeting Participants

Barbara Ainsworth, PhD, MPH *
Arizona State University

David Bassett, PhD *
University of Tennessee

David Berrigan, PhD *
National Cancer Institute

Bridget Borgogna **
Centers for Disease Control and Prevention

David Brown, PhD
Centers for Disease Control and Prevention

Nancy Butte, PhD *
Baylor College of Medicine

Susan Carlson, MPH
Centers for Disease Control and Prevention

Carl J. Caspersen, PhD, MPH
Centers for Disease Control and Prevention

Kong Chen, PhD
National Institute of Diabetes and Digestive and Kidney Diseases

Scott Crouter, PhD
University of Massachusetts, Boston

Joan Dorn, PhD
Centers for Disease Control and Prevention

Ginny Frederick, MS
University of Tennessee

Janet Fulton, PhD *
Centers for Disease Control and Prevention

Carmen Harris, MPH
Centers for Disease Control and Prevention

Steve Herrmann, PhD *
University of Kansas

Kristin lssacs, PhD
Environmental Protection Agency

Sarah Lee, PhD
Centers for Disease Control and Prevention

Bob Malina, PhD *
Tarleton State University

Bob McMurray, PhD *
University of North Carolina

Mindy Millard-Stafford, PhD
Georgia Institute of Technology

Don Morgan, PhD *
Middle Tennessee State University

Russell Pate, PhD *
University of South Carolina

Karin Pfeiffer, PhD *
Michigan State University

Kate Ridley, PhD *
Flinders University, Australia

Anne Rodgers***
Science Writer

Tom Rowland, MD *
Baystate Children's Hospital

Andrea Torres, MPH
Centers for Disease Control and Prevention

Stewart Trost, PhD *
Oregon State University

Kathy Watson, PhD
Centers for Disease Control and Prevention

* Presenters
** Meeting facilitator
*** Science Writer

# *Appendix 2: Meeting Agenda*

| ***Thursday, April 19*** | | |
|---|---|---|
| **Time** | **Title** | **Presenter** |
| 8:15 – 8:30 | Welcome | *David Berrigan* |
| 8:30 – 8:50 | Goals of the Workshop | *Janet Fulton* |
| 8:50 – 9:10 | Facilitated activity | *Bridget Borgogna* |
| 9:10 – 9:30 | The Need for an Updated Compendium for Youth: Benefits and Challenges | *Russell Pate* |
| ***GOAL 1: Improving the Acceptability and Accessibility of the Youth Compendium*** | | |
| **History and Use of Adult and Youth Compendia: Overviews and Lessons Learned** | | |
| 9:30 – 9:50 | Overview of Compendium for Adults | *Barb Ainsworth* |
| 9:50 – 10:10 | Lessons Learned from the Adult Compendium | *Steve Herrmann* |
| 10:10 –10:40 | Overview and Lessons Learned from the Youth Compendium | *Kate Ridley* |
| 10:40 – 11:10 | BREAK OUT GROUPS TO ADDRESS THE FOLLOWING QUESTIONS:<br>1. To reformat the Compendium, what are key issues to address?<br>2. How might we go about providing a publicly-accessible Youth Compendium?<br>3. To update the Youth Compendium, what are key issues to address?<br>For example:<br>How should we code activities?<br>How might we designate the measurement source of the data?<br>How much new data are out there? | *Borgogna/Berrigan/ Fulton* |
| 11:10 – 11:45 | LARGE GROUP REPORTING AND DISCUSSION | *Bridget Borgogna* |
| 11:45 – 12:00 | BREAK | |
| 12:00 – 1:00 | Presentation and LUNCH<br>User-friendly PA products Supported by NCCOR: Measures Registry and Catalogue of Surveillance Systems | *David Berrigan* |
| ***GOAL 2: Improving the Accuracy of EE in the Youth Compendium*** | | |
| **Indirect Calorimetry and Monitoring Devices to Measure EE** | | |
| 1:00 – 1:20 | Direct Measurement of EE in Youth -- History and Present State of the Art | *Bob McMurray* |
| 1:20 – 1:40 | Estimation of EE with Metabolic Chambers | *Nancy Butte* |
| 1:40 – 2:00 | Estimation of EE with Mechanical Devices | *Stewart Trost* |
| 2:00 – 2:30 | DISCUSSION<br>1. What is the most feasible EE method(s) to incorporate into the Youth Compendium?<br>2. What are the next steps to make this happen?<br>3. What is the most important first step? | *Bridget Borgogna* |
| 11:45 – 12:00 | BREAK | |
| **Challenges and Opportunities for EE Measurement** | | |
| 2:45 – 3:05 | Inter-individual Variation in EE | *Karin Pfeiffer* |
| 3:05 – 3:25 | Training and Biomechanical Efficiency in Estimating EE | *Don Morgan* |

| | | |
|---|---|---|
| 3:25 – 4:15 | BREAK OUT GROUPS<br>To improve the accuracy of EE estimates from the Youth Compendium:<br>1. What are your suggestions?<br>2. What are next steps and timeline?<br>3. What are strengths and challenges of developing a repository of energy expenditure values (published and unpublished) for youth?<br>For example:<br>What data should we extract from published studies?<br>What data should be included from unpublished findings? | *Borgogna/Berrigan/ Fulton* |
| 4:15 – 5:00 | Large group reporting and discussion | *Bridget Borgogna* |
| ***Friday, April 20*** | | |
| **Review of First Day** | | |
| 8:30 – 9:00 | Review of first day + goals of today + midnight ideas | *Fulton/Berrigan* |
| **Interpolation and Estimation of EE** | | |
| 9:00 – 9:20 | Estimation of EE based on Adult Data | *David Bassett* |
| 9:20 – 9:40 | EE in Children and Adolescents: Perspectives from Growth and Maturation | *Bob Malina* |
| 9:40 – 10:00 | DISCUSSION<br>Are there usable techniques for estimation of MET scores based on adult data with or without information about growth and maturation? | *Bridget Borgogna* |
| 10:00 – 10:15 | BREAK | |
| **Synthesis of Needs to Move Toward Standardized Methods for Youth Energy Expenditure and Presentation** | | |
| 10:15 – 10:35 | Summary of Challenges and Opportunities | *Tom Rowland* |
| 10:35 – 11:30 | BREAK OUT GROUPS<br>1. What are key needs for re-design and updating?<br>2. What are key issues for data and measurement refinement?<br>3. What papers should come from this Workshop? | *Fulton/Berrigan/ Borgogna* |
| 11:30 – 12:00 | LARGE GROUP REPORTS AND DISCUSSION<br>1. What are key lessons learned to incorporate into the next version of the Youth Compendium?<br>2. What are next steps to accomplish them? | *Bridget Borgogna* |
| 12:00 – 1:00 | WORKING LUNCH | |
| ***Goal 3: Developing a Publication Plan and Timeline*** | | |
| 1:00 – 1:45 | Further Discussion of Standardizing Youth EE Data Collection and Sharing<br>1. Are we near a consensus?<br>2. How and where could this be presented?<br>3. Who would take the lead? | *Bridget Borgogna* |
| 1:45 – 2:45 | Wrap Up, Paper Plans, Departure<br>1. What are key research needs?<br>2. Paper ideas?<br>3. Authorship teams?<br>4. Lead authors?<br>5. Timeline and process? | *Bridget Borgogna* |
| 2:45 – 3:00 | Closing Remarks | *Fulton/Berrigan* |