STEP RATE RECOMMENDATIONS FOR MODERATE ACTIVITY WALKING IN CHILDREN

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Moderate to vigorous physical activity (MVPA) is related to numerous health benefits in youth (23). Based on these benefits, the Centers for Disease Control and Prevention (CDC) recommends that children participate in 60 minutes of physical activity everyday and most of this activity should at the moderate to vigorous intensity level (18). Accelerometer data from the 2003-2004 National Health and Nutritional Examination Survey (NHANES) suggest low adherence to the 60 minute MVPA recommendation (24). Less than half of the children aged 6-11 and only 8% of adolescents aged 12-15 accrued 60 minutes of MVPA per day.

Physical activity promotion is a national health goal because few youth meet CDC's 60 minute recommendation for MVPA per day (24). The accurate assessment of physical activity (PA) intensity is an important component of physical activity promotion for researchers and practitioners (12, 20). Instruments that objectively measure physical activity such as accelerometers and pedometers have been used to determine MVPA in youth (16, 26). Accelerometers have high validity and reliability in predicting MVPA in youth (16) and are now used in national surveillance systems to assess youth physical activity longitudinally (24). But, accelerometry use in physical activity promotion is still problematic, mainly, because of the high cost per unit (up to around $400) and the lack of consensus on accelerometer cut-points that determine moderate and vigorous thresholds (12).

Pedometers have also been validated for use in research and practice to assess physical activity in youth (26) but until recently have not been able to quantify intensity. Step frequency per minute ($steps \cdot min^{-1}$) has been used to quantify moderate physical activity based on the premise that a given step rate per minute equates to a threshold for

moderate activity (5, 11). Beets, Patton, & Edwards (2005), found over 90% accuracy between actual step counts and actual recorded values versus the pedometers' recorded step counts and activity time during self-paced walking.

To determine metabolic equivalent, studies have traditionally measured metabolic response to walking at different speeds on a treadmill to determine moderate thresholds. Walking speeds between 3.0 – 4.0 mph in adults and 2.5 – 3.5 mph in children (8-12 yrs) produced MET levels (3.2 – 4.3 METs) that fell within MVPA levels (12). Adult studies have estimated that about 100 SPM for adults is an accurate measure of MVPA for men and women (25). No studies have simultaneously measured steps per minute values and MET levels to determine MVPA threshold in youth.

Based on the walking speeds that produced MET levels equivalent to moderate physical activity in youth determined by Harrell et al., 2005, a recent study measured the number of steps taken on a treadmill at 3, 3.5, and 4 mph (11). The authors recommended that a 120-140 SPM range would be a reasonable recommendation for MPA threshold for youth 10-12 years of age. This was a preliminary study and step per minute recommendations were not reported for height.

One study used heart rate monitors and percentage of heart rate reserve (HRR) to determine metabolic equivalent in a special population of youth with an intellectual disability (ID) (6). The authors reported 122 SPM was the average minimal threshold for determining MVPA. Height-specific estimates ranged from 135 SPM for the shorter participants (109cm) to 112 SPM for the tallest participants (186cm). These data cannot be generalized to normal populations of youth because youth with ID have lower levels of physical activity and cardio-respiratory fitness, and higher levels of obesity.

Weyand and colleagues (28) looked at energy cost from a biomechanical perspective. Using different predictive equations including the Schofield (for REE), the Froude number equation (equivalent speeds for leg length), and the equation for the metabolic cost of transport for mass-specific subjects, they were able to conclude that individuals of different stature, age, and mass use the same amount of energy, equal to their stature, while walking equal, horizontal distances. As their evidence suggests, height differences of the youth should be insignificant when used to calculate MVPA at walking speeds.

Purpose and Rationale. Walking intensity measured metabolically to determine step rate recommendations in adults has been well studied (13, 21, 25). Initial step rate recommendations for youth have been established without investigating physiological response at those step rates (11). Based on these limitations the primary purpose of the study is to determine age-adjusted metabolic equivalent (A-AME) (12) by simultaneously measured VO_2 via indirect calorimetry and steps per minute to determine step per minute recommendations for youth.

Methodology

Participants. Approximately 100 recruitment forms were distributed to a local charter school (grades 5 & 6) and a youth soccer league (U11-U12 age groups). Parental informed consent and participant informed assent was submitted prior to the study for twenty five (16 girls, 9 boys), with a mean age of 10.9 (± .7) years. The ethnic distribution was comprised of White (44%), Native Hawaiian (16%), Japanese (16%), Filipino (12%), Samoan (8%), and Chinese (4%). All participants were successfully screened for cardiovascular, lung, bone and joint, and other contraindications using a modified questionnaire developed for youth exercise testing (PARmed-X; ACC/AHA, 1997). Approval from the University's Institutional Review Board was obtained prior to data collection.

Design. The study was conducted at the University's exercise laboratory over a period of 18 weeks. All children were driven to the laboratory in the morning for testing. Participants were assessed on Saturday and Sunday mornings. Testing times were assigned between 8 and 10 AM.

Procedures. Each individual's testing and data collection were completed on one day. Children were instructed to fast, water only, overnight (27) for at least 6 hours prior to testing session in order to collect accurate REE measurements (17). Participants were instructed to wear comfortable, light clothing, and covered athletic shoes. EE and REE were measured by the use of indirect calorimetry. Participants were fitted with a noseclip, and a pediatric silicone mouthpiece, consisting of a two-way nonrebreathing valve (Hans Rudolph Inc., Kansas City, MO) that directs air into the ventilation turbine, and into the

gas analyzer. A primary gas standard (6% CO2, 14.01% O2) was used for gas calibrations. The oxygen analyzer, used to measure EE and REE, was calibrated before every use. Breath by breath data was collected and converted to average outputs for every 30 seconds and stored on the laboratory computer.

Clear instructions (See Appendix D), were given to all participants and participants were also given an opportunity to ask questions regarding the test. Upon full comprehension of the instructions (See Appendix D) and introduction to treadmill, participants were hooked up to the oxygen analyzer in order to measure EE throughout the test. For our purposes, EE ($kcal \cdot kg^{-1} \cdot h^{-1}$) will be used interchangeably with oxygen uptake ($mL \cdot kg^{-1} \cdot min^{-1}$). 1 MET is equal to 1 $kcal \cdot kg^{-1} \cdot h^{-1}$, and in turn is equal to 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$of O_2. Due to the fact that we are looking at EE in terms of the PA compendium, we have presented our data using these units, rather than allometrically scaling the data (Harrel, 2005).

All outside distractions including music were eliminated from testing environment. Stringent quality control protocols were followed for all activities.

Data Collection.

Anthropometric data, including height and body mass, was collected upon arrival at the laboratory. Body mass was measured using a calibrated scale with subjects' clothes on but shoes off with the Secca digital scale and measured to the nearest 0.1 kg. Height was then measured to the nearest 0.1 cm, using a wall-mounted stadiometer. Participants' height was taken while barefoot. Values were recorded and Body Mass Index (BMI) was calculated using the child and teen BMI calculator by the CDC. Age-sex specific BMI

percentiles were used to classify youth into three categories: healthy (<85th percentile), overweight (>85th and <95th percentiles), and obese (>95th percentile) according to CDC growth charts (NCHS, 2011).

REE. In order to measure REE, subjects were placed in a quiet and dimly lit room and were hooked up to the oxygen analyzer and restricted to mouth only breathing by the use of a noseclip. They were allowed to rest for 5 minutes in a supine position before values were recorded (27). EE was measured for 15 minutes while the child was quiet but awake and remained in the supine position (12, 4).

Walking Trials. Walking data was collected from each participant after full comprehension of instructions regarding activities and transition times between tests. Two phases of the testing session included the following: (a) warm-up and (b) 3 walking trials on a treadmill (11 minutes).

Two trained assessors counted steps with a hand tally during each walking trial and inter-rater reliability between the two assessors exceeded 99%. No other objective measure (pedometer, accelerometer, etc.) was used to assess steps per minute to eliminate participant burden of multiple tasks during the walking trials.

Participants completed a single 11 minute long bout of exercise that consisted of a 2 minute warm up at a self-selected pace, followed by 3 stages, each 3 minutes long. This protocol was chosen because the American College of Sports Medicine (ACSM) suggests that the protocol used should have stages that are approximately 2-3 minutes in length and the test protocol should only be between 8-12 minutes for maximal testing. In this study, participants were not under maximal testing conditions. The self-selected walking pace

was the participant's normal walking pace, and participants were instructed to let the investigator know when the treadmill reached the correct pace. Investigator increased the speed .1 mph more in order for the participant to be sure they have chosen the right speed. Each of the following stages was progressively greater in intensity. The treadmill was set at the speeds of 2.5, 3, and 3.5 mph, respectively, which, according to the adult compendium, typically range between 3 and 3.8 METS (12). Harrell, et al. (2005) reported that speeds between 2.5-3.5 mph reached MET levels equivalent to moderate physical activity in children between the ages of 8-12 years old. We have not seen any studies that show these speeds to produce vigorous activity levels in children (>6 METs) nor is it a speed that requires running or jogging. This was also supported by a pilot study using University students.

Each stage began with the participant already on the treadmill to reduce risk of injury of getting on and off a moving belt. The stages began with a verbal countdown of "3, 2, 1, begin". At this point, the two trained assessors began counting steps (during the 2 minute warm-up and the 3 minute stages). During the last five seconds of each stage, the researcher gave a verbal countdown of, "5, 4, 3, 2, 1, OK". The "OK" was a cue to the assessors to stop the step count at that time. Participants were instructed not to stop walking at the word "OK". Step counts were quickly recorded and the treadmill speed was increased to the next level. This process was repeated again throughout all stages. Upon completion of the test, VO_2 outputs from the oxygen analyzer were recorded and stored on the laboratory computer.

Data Analysis.

Descriptive data (Table 1) was summarized and examined for violations of normality and outliers. One participant was eliminated from the analysis because the individual was unable to follow the protocol. Values indicated that it was a true outlier. REE was obtained by taking the average of 9-minutes from the 15 time frame. The first 5 minutes and last minute were excluded to account for extra EE from mask introduction and removal (12). To calculate adjusted METs (A-MET) during the walking trials, the participant's absolute oxygen uptake ($mL \cdot kg^{-1} \cdot min^{-1}$) was divided by their resting oxygen uptake. Inter-rater reliability scores were determined between the 2 step count assessors and scores were averaged to determine average step count per minute for each stage of the metabolic testing. Step count scores were only considered acceptable if they exceeded 98% reliability. After each test, calorimetry data was downloaded and breath by breath VO_2 data was averaged for every 30 seconds throughout the test. MET values were calculated from the VO_2 data that was collected and then dividing by REE and A-MET. CDC BMI-for-age growth charts were used to determine BMI percentiles and corresponding weight status categories for underweight (< 5th), healthy weight (5th to < 85th), overweight (85th to < 95th), and obese ($\geq$ 95th) (NCHS, 2011).

Statistical Analysis.

Analysis of Variances Procedures. To determine group differences a series of one-way analysis of variance (ANOVA) procedures were conducted on all demographic/biological, resting, and walking trial variables with gender, sports participation (yes, no), age (9,10,11,12), weight status category (underweight, healthy,

overweight, obese), and ethnicity (Chinese, Filipino, Japanese, Native Hawaiian, White, Samoan), and as the factors.

Similar to Marshall and Rowe, multiple analytical approaches were used to determine steps per minute recommendations - multiple and mixed-model regression, and ROC curve analysis.

Multiple regression. A series of multiple regression analyses were conducted to determine if SPM predicted metabolic outcomes for each of the walking trials (2.5, 3.0, 3.5 MP). The metabolic outcomes, VO_2 and A-MET, were used in the analyses respectively. Height was entered into the analysis after SPM to determine the potential effect in the prediction. Casewise diagnostics were computed prior to regression analysis and one subject was found to be beyond 3 standard deviations. This outlier was removed based on previous recommendations (2) and the final sample for which all analyses were conducted included n =23.

ROC curve. Receiver operating curve analysis were used to determine the percent of subjects that were correctly classified for meeting step rate recommendations.

Results

Descriptive Statistics. Mean, standard deviations, and 95% confidence intervals for demographic/biological, resting, and walking trial variables are presented in Table 1. The mean BMI was 17.8 (± 2.9) and based on CDC BMI-for-age growth charts, 17 of the 23 participants (74%) were classified as healthy weight, 2 (9%) underweight, 2 (9%) overweight, and 2 (9%) obese. Compared to the most recent overweight and obesity prevalence data in US youth (Odgen, 2010), approximately 18% of youth in the current sample were classified as overweight and obese compared to ~35% percent of US youth. Fifty seven percent (13 of 23) of the sample reported that they currently participate in a sport, and this may partially explain the lower overweight/obesity prevalence.

Analysis of Variance Procedures. The only significant gender difference found between boys and girls was on SPM during the normal pace walking trial, $F(1, 21) = 9.3$, $p < .01$. In this sample, girls (94.6 spm) averaged ~14 more steps·min^{-1} compared to boys (81 spm). Youth that participated in sports were significantly shorter, $F(1, 21) = 7.4$, $p < .05$, (145 cm vs. 154 cm) and leaner $F(1, 21) = 5.0$, $p < .05$, (36.7 kg vs 43.7 kg). The only significant age main effect was height, $F(3, 19) = 5.6$, $p < .01$, and as expected, the older youth were taller than the younger youth, however, all follow-up pairwise tests were non-significant using Bonferroni adjustments to control for type 1 errors. One weight status category main effect was significant on heart rate for the 3.5 MPH trial, $F(3, 19) = 4.7$, $p < .01$, with the general trend of higher the weight status the higher the HR. However, none of pairwise comparisons were significant after Bonferroni adjustments. No significant ethnic differences were found on any of the demographic/biological, resting, and walking trial

variables. Based on the limited number of group differences, the data set was combined for the analytical approaches used to determine step rate recommendations/cut points.

Multiple regression. Step rate (steps·min^{-1}) significantly predicted VO_2 (mL·kg^{-1}·min^{-1}) for both the 2.5 MPH ($F(1,21) = 7.3$, $p < .01$) and 3.0 MPH trials ($F(1,21) = 7.8$, $p < .01$) accounting for 26% and 27% of the variability respectively. The second model was conducted to evaluate whether height predicted VO_2 over and above step rate. Height did not add significant variance to the model after controlling the effects of step rate in either the 2.5 MPH trial (*F Change*(1,20) = 2.2, $p = .15$) or the 3.0 MPH trial (*F Change* (1,21) = 2.9, $p = .10$). For the 2.5 MPH walking trial, the equation VO_2 (mL·kg^{-1}·min^{-1}) = .08(SR) + 4.909 (SR = step rate) solved for a step rate of 112 step·min^{-1}. For the 3.0 MPH walking trial, the equation VO_2 (mL·kg^{-1}·min^{-1}) = .078(SR) + 6.859 solved for a step rate of 121 step·min^{-1}. Step rate did not significantly predict VO_2 (mL·kg^{-1}·min^{-1}) for the 3.5 MPH walking trial ($F(1,21) = .02$, $p = .90$) nor with height added to the model, (*F Change*(1,20) = .13, $p = .72$). Step rate did not significantly predict 3.0 or more A-MET for either the 2.5 MPH, ($F(1,21) = ..63$, $p = .44$), 3.0 MPH ($F(1,21) = .02$, $p = .04$), or 3.5 MPH walking trials ($F(1,21) = .58$, $p = .45$).

ROC analysis. Receiver operating characteristic curves were also developed to determine step rate cut points based on achieving ≥ 3.0 A-MET and data were initially analyzed for all 3 walking trials. Step rate cut points did not have the ability to significantly distinguish between < 3.0 and ≥ 3.0 A-MET at $p < .05$ in any of the walking trials. The 3.5 MPH trial had the highest area under the curve (.727 (AUC), .095 (SE), $p = .45$) and the optimal step rate cut point was 124 step·min^{-1}. Using 124 step·min^{-1}, 76% of

those in moderate intensity would be correctly classified and 0% would be incorrectly classified.

Discussion

Several indirect calorimetry studies have used multiple methodological and analytical approaches and have all recommended a heuristic step rate of 100 steps·min^{-1} for moderate activity walking in adults (21, 1, 13). A recent study refined the recommendation to include height specific cut points that range from 90 steps·min^{-1} for a 78" adult to 113 steps·min^{-1} for 60" adult (21). For youth, a pilot study proposed an initial step rate range of 120-140 steps·min^{-1} for moderate intensity walking for children (10-12y), but no indirect calorimetry was used to make the determination (11). An even more recent study on youth with intellectual disabilities (10 female, 28 male, 11.8 $\pm$ 1.8 y), reported that 122 steps·min^{-1} is the average minimal threshold for MVPA. However, height and age-specific threshold recommendations varied from 112-135 steps·min^{-1} (6).

This is the first study to use indirect calorimetry to validate a step rate cut point for moderate intensity walking in children. A major strength of the study is that REE was measured in each participant and used to determine the more precise age-adjusted metabolic equivalent (8) versus using the adult constant (3.5 mL·kg^{-1}·min^{-1}) that underestimates youth EE (12). Despite the strength of the study, we found substantial error using step rate to predict treadmill walking energy expenditure for this sample of 9-12 year old children. Step rate (steps·min^{-1}) did not significantly predict age-adjusted moderate activity for any of the three walking speeds using either linear regression or ROC curves. As seen graphically in figures 1 thru 3, step rate and A-ME are clearly not related in any of the 3 different walking trials.

Step rate (steps·min^{-1}) did predict absolute VO_2 (mL·kg^{-1}·min^{-1}) at 2.5 and 3.0 MPH respectively. When predicting absolute VO_2 (mL·kg^{-1}·min^{-1}), without using REE to determine age-adjusted moderate intensity, step rate predicted 26% and 27% of the variance in VO_2 (mL·kg^{-1}·min^{-1}) at 2.5 and 3.0 MPH respectively. Compared to studies in adults, we found that the strength of this relationship, expressed as the percent of variance explained, within ranges reported by Marshall (15-41%), lower than Rowe (38%), and much lower than Tudor-Locke (80-83%) and Abel (71-91%). Height did not significantly add to the prediction model unlike the most recent study in adults (21) and the study of children with (ID).

A step rate of 112 steps·min^{-1} predicted 13.91 mL·kg^{-1}·min^{-1} for the 2.5 MPH walking trial and 121 steps·min^{-1} predicted 16.33 mL·kg^{-1}·min^{-1} for the 3.0 MPH walking trial. Comparing step rate cut points between the current study of children and adult studies is not advisable because most to the adult studies used the common adult constant (3.5 mL·kg^{-1}·min^{-1}) to determine METs.

Using only descriptive statistics and limited inferential statistics, at 2.5 MPH the A-MET mean (2.9) and confidence intervals (2.8 - 3.0) were just lower than the 3.0 moderate cut rate. At 3.0 MPH, the A-MET mean (3.4) and confidence intervals (3.2-3.6) just exceed the 3.0 moderate cut rate. The mean step rate (121 steps·min^{-1}) and confidence intervals (117 – 124) at this speed, approximates the lower range of 120 steps·min^{-1} by Graser and the 122 steps·min^{-1} by Beets. A general step rate recommendation of 120 steps·min^{-1} for 9-12 year old children seems logical based on the current study, and the work of Graser and Beets.

SPM. Our study showed the same rate as Graser, where at 3 and 3.5 mph, MVPA thresholds are approximately 121 and 131 steps·min^{-1}. It is also important to note the trend, where as speed increases the inverse step rate gets stronger – Pearson correlations at self-pace (.345), 2.5 mph (-.285), 3 mph (-.530), and 3.5 mph (-.693).

Height. In this sample, none of the bivariate correlations were significant between height and VO_2 (mL·kg^{-1}·min^{-1}), and A-MET for any of the walking trials (2.5, 3.0, and 3.5 MPH). An important inverse relationship was found between height and step rate among the walking trials. As the speed increased the relationship became much stronger as illustrated in figures 1 thru 3. The correlation increases from -2.9 (2.5 MPH), to -.53 (3.0 MPH), and to -.69 (3.5 MPH).

Normal walking pace. Another finding from our study comes from our warm-up stage, where the participants were asked to walk at their normal walking speed. Although we conducted the study in a laboratory, we did find that chosen everyday walking speeds were significantly slower than speeds that would elicit moderate level intensity. If done in a field setting results may be different although practice time was allowed to get youth comfortable on the treadmill. We found that the mean chosen walking speed was about 1.3 mph. From this, we can conclude that, if given the choice, children would most likely not walk at speeds that would require moderate intensity. This could be due to children choosing to walk and talk with friends, the multitasking of walking and using electronic devices, or findings from, (Weyand et al, 2010), that children will walk as economically as possible.

REE and REE vs. Adult Values. Trained adults with increased muscle mass have a significantly higher REE than do their more sedentary counterparts. Known variability in

youth REE due to growth, hormones, and increasing muscle mass as well as other factors exist and make it difficult to pinpoint the exact cause of the difference between youth and adult REE.

To further complicate the difficulty of step rate recommendations for youth A-MET, both resting and active energy expenditure varies by pubertal stage (7). Resting EE is higher in prepubertal compared to postpubertal youth, and approximates adult values at Tanner stage 5 (12). The values in the current study are congruent with these differences. The mean resting energy expenditure of 9-12 year old boys and girls (n=23) was 4.9 $\pm$ 0.7 $mL \cdot kg^{-1} \cdot min^{-1}$, which was 1.0 $mL \cdot kg^{-1} \cdot min^{-1}$ lower than a group (n=129) of 8-12y boys/8-11y girls (5.92 $\pm$ 1.41 $mL \cdot kg^{-1} \cdot min^{-1}$) but 0.3 $mL \cdot kg^{-1} \cdot min^{-1}$ higher than 13-15y boys/12-14 y girls (n=83; 4.58 $\pm$ 1.22 $mL \cdot kg^{-1} \cdot min^{-1)}$ reported by Harrell et al. Alternatively, (Ridley & Olds, 2008) reported that out of 54 studies, healthy children aged 6-17.9 year old boys and girls, would elicit a REE of 4.59 $\pm$ 1.07 $mL \cdot kg^{-1} \cdot min^{-1}$, which is similar to what we are reporting in our study. This value was used as a basis to begin creating the youth PA compendium. Future studies need to consider the maturation age of the sample to accurately measure resting and walking EE to accurately determine step rate cut points of pre and post pubertal youth.

Similar to findings reported by Harrell et al., we also conclude that using 1 MET as 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ in children is inappropriate and can lead to underestimating actual energy expenditure. The need to investigate MET levels in youth is essential because using adult MET values to predict EE in children has significant biases when using METs to determine MVPA intensities (20). It has previously been noted that differences in REE of adults versus the REE of youth, can cause significant biases to arise in the computation of

MET values and this type of error can cause confusion as to what the true MVPA range is (12).

Group Differences. Consistent with adult studies limited gender differences were found (13, 21). Our data shows that there are no gender differences in REE, A-MET, and step counts. Although we may have had a relatively small amount of subjects, we have similar findings to other studies that show no gender differences in youth EE results (12). Also, due to the similar heights of all participants, and the set treadmill speeds, we found that at these set speeds, there were no gender differences in step rate per minute. Other youth studies have also shown similarities in step counts at constant speeds, and thus recommending generalizable step rates (11, 28).

Sports participation. No significant differences were found on either resting or walking energy expenditure variables between youth that reported sport participation and youth that did not. Similarly, a study looking at lean vs. obese prepubertal children shows that there are no differences in REE or TDEE between the two populations (9). However, trends should be noted. Resting EE was higher (0.4 $mL \cdot kg^{-1} \cdot min^{-1}$) in sport participants similar to studies that have reported trained adults have higher REE than sedentary adults (22). All the walking trial A-METs were lower in trained, or sport participating, individuals which is also consistent with youth and adult studies (22, 19). Future studies may need to consider sport participation/cardiovascular fitness level in deciding methods and analyses to determine the relationship between step rate and energy expenditure.

Daily physical activity recommendations. Our findings suggest that the MVPA step rate threshold for youth is 120 $steps \cdot min^{-1}$. With national recommendations of at least 60

minutes of MVPA, this would equate to 120 x 60 = 7,200 steps/day. A general recommendation of 7, 000 steps/day may be appropriate for youth.

Strengths and Limitations. A major strength of our study was that we were able to collect resting metabolic measurements from the youth participants. Many studies which looked at step rates and counts for youth energy expenditure assessments did so without taking metabolic measurements. We were able to use the A-MET's that we collected to assess the MET values of EE outputs from the participants' walking trials. The RMR values that we were able to collect provide further evidence that using 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ as 1 MET is inaccurate.

Future studies should consider selecting samples of heterogeneous groups or have large enough samples sizes to perform subgroup analyses. Group differences have been found in both resting and exercise VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$) and this may influence the relationship between step rate and energy expenditure. One example, being 12 year old females in Tanner Stage 5, tend to show a tendency to have a lower REE then their prepubertal counterparts (12 & 14). A study looking at resting and exercise VO_2 of obese and lean children, has been observed (9), where they had a sampling of 46 participants, and results showed no differences in REE and exercise VO_2 of the obese and lean participants. (6), more recently had a heterogeneous sample of 38 children and adolescents with intellectual disabilities, and with the use of heart rate monitors and pedometers, found that both height and sex were significant variables and thus need to be corrected for resulting in boys having a slightly higher step rate then the females. In addition, (Goran, et al, 1998), conducted a study that looked at differences in sex, seasonality, ethnicity, and geographic location and the effects on total energy expenditure, REE, and activity-related energy

expenditure. Using 232 children, ages 4-10 years, from White American, African American, Guatemalan, and Native American ethnic groups, they found that seasons affect activity energy expenditure and in turn influences total energy expenditure, that boys have a higher REE than girls, and that there were no significant REE differences in children from the different ethnicities but total energy expenditure was lower in Guatemalan children due to their lower activity energy expenditure (10).

Other potential confounders in the relationship between step count and energy expenditure as well as height and REE values were non significant unlike other studies (6) but our values compared well to other studies.

Identifying Tanner Stages. Post analysis between 4, 12-year-old girls, found no differences among resting or walking trial variables. One of the weaknesses of our study is that we did not use the Tanner Stages to assess our A-MET for the 12-year-old girls. Tanner stages are commonly discovered through the use of a self-reporting questionnaire, the Pubertal Development Scale (PDS), which has a five-item subscale that are made up of specific developmental characteristics and have separate ones for males and for females (14, 15). The first Tanner Stage includes 8-12 year old boys and 8-11 year old girls. This is in order to account for earlier pubertal maturity of girls. In our study, we grouped all 8-12 year old boys and girls in the same grouping. Although boys have been shown to have a slightly higher REE then girls, and higher in pubertal and prepubertal boys and girls respectively (7), our data did not show any significant differences between the 12 year old girls and the rest of the sample among any of the demographic/biological and walking trial variables. We also note that the lower number of participants (n=23) may have been a

contributing factor although much of our data proved to be consistent with various parts of other studies (11, 12).

Future studies should be performed in collecting youth RMR data and grouping by pubertal stages in order to look at MVPA activities in order to fully complete a true pediatric PA compendium. Due to the differences in RMR of adults versus the RMR of youth, significant biases can arise in the computation of MET values and this type of error can cause confusion as to what the true MVPA range is (8). Youth have different bodies, shorter legs, smaller lungs, etc. than do adults and those differences will result in the two populations to have different EE while participating in physical activities. A review (Ridley, & Olds, 2008) found that the MET cost of walking and running increases with both age and speed of walking and running. While, on the other hand, VO_2 for that same data set increases with speed but decreases with age (from preschool to adolescence). This inconsistency is one of the reasons why there is a need to look at the EE of those activities in children, further (20). Based on this initial study in youth, and, weak and inconsistent results, the 120 $step \cdot min^{-1}$ recommendation for moderate activity in youth should be used with caution.

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Table 1. Descriptive statistics for demographic variables and walking trial variables.

			95% Confidence Intervals for Mean			
Variable	Mean	SD	Lower bound	Upper Bound	Minimum	Maximum
Height (cm)	148.5	8.1	145.0	152.0	130.0	167.0
Weight (kg)	39.4	8.0	36.0	42.9	26.9	62.4
Age	10.9	0.9	10.5	11.3	9.0	12.0
BMI for Age	17.8	2.9	16.6	19.0	14.5	26.5
Resting HR	68.7	10.7	64.1	73.4	51.0	98.0
VO2 REE (5.5-14.5 min) (mL·kg¯1·min¯1)	4.9	0.7	4.6	5.2	3.7	6.3
Normal Walking Pace (mph)	1.3	0.3	1.2	1.4	8.0	14.4
HR	91.3	9.8	87.0	95.6	71.5	117.5
VO2 (mL·kg¯1·min¯1)	10.8	1.5	10.1	11.4	8.0	14.4
A-MET	2.2	0.3	2.1	2.4	1.7	3.2
METS (adult 3.5)	3.1	0.4	2.9	3.3	2.3	4.1
Steps Per Min	89.7	12.9	84.1	95.3	65.0	115.3
2.5 MPH						
HR	99.0	10.5	94.5	103.5	84.5	126.0
VO2 (mL·kg¯1·min¯1)	13.9	1.1	13.4	14.4	11.7	15.7
A-MET	2.9	0.3	2.8	3.0	2.3	3.5

METS (adult 3.5)	4.0	0.3	3.8	4.1	3.3	4.5
Steps Per Min	112.0	7.0	109.0	115.0	100.7	124.3
3.0 MPH						
HR	106.6	11.4	101.6	111.5	82.5	133.0
VO2 (mL·kg¯1·min¯1)	16.3	1.1	15.9	16.8	14.3	18.3
A-MET	3.4	0.5	3.2	3.6	2.6	4.5
METS (adult 3.5)	4.7	0.3	4.5	4.8	3.3	4.5
Steps Per Min	121.1	7.2	117.9	124.2	110.0	135.3
3.5 MPH						
HR	115.1	12.5	109.7	120.5	81.5	146.5
VO2 (mL·kg¯1·min¯1)	19.3	1.3	18.7	19.9	16.9	22.7
A-MET	4.0	0.6	3.8	4.3	2.9	5.1
METS (adult 3.5)	5.5	0.4	5.3	5.7	4.8	6.5
Steps Per Min	130.6	9.4	126.5	134.7	116.8	150.3

Table 2. Mean VO2 (mL·kg¯1·min¯1), adjusted metabolic equivalents (A-MET) and compendium of physical activities MET level (*n*=23).

Walking Trial (mph)	VO2 (mL·kg¯1·min¯1)	VO2 (mL·kg¯1·min¯1) 95% CI	A-MET	A-MET 95% Cl	VO2/3.5	METS from Compendium
2.5	13.91	13.43, 14.39	2.90	2.75, 3.04	3.97	3
3.0	16.33	15.87, 16.08	3.41	3.21, 3.62	4.67	3.3
3.5	19.29	18.72, 19.85	4.04	3.78, 4.29	5.51	3.8

a A-MET = VO2 of walking trial/VO2 at rest.
b Difference between measured VO2 divided by 3.5 and MET value = <0.0001.
c METS from Compendium values derived from Ainsworth et al. 2000

Table 3. Walking trial speed (mph), mean steps per minute (SPM), and mean adjusted metabolic equivalents (A-MET) (*n*=23).

Walking Trial (mph)	SPM	A-MET
2.5	112	2.8955
3.0	121	3.4131
3.5	131	4.0359

Table 4. Pearson correlation coefficients between steps per minutes and height for each walking trial.

Walking Trial	Correlation	Significance
Self-Pace (1.3 MPH)	.345	.054
2.5 MPH	-.285	.094
3.0 MPH	-.530	.005
3.5 MPH	-.693	.000

Table 5. Comparison of mean step rate (steps·min^{-1}) over different treadmill speeds across studies by gender.

			Treadmill Speeds					
	Height inches (cm)		2.5 MPH		3.0 MPH		3.5 MPH	
Gender	Current	Vincent-Graser	Current	Vincent-Graser	Current	Vincent-Graser	Current	Vincent-Graser
Girls	58 (146)	58 (146)	113 ±7	NR	123 ±7	123 ±9	133 ±9	133 ±9
Boys	60 (152)	59 (150)	111 ±7	NR	119 ±6	120 ±10	127 ±9	131 ±7

NR = no data reported.

Table 6. Hypothetical association among step rate (steps·min^{-1}), treadmill speeds (MPH), and adjusted metabolic equivalents (A-MET).

Step Rate (steps·min^{-1})	Treadmill speed (MPH)	Adjusted Metabolic Equivalent (A-MET)
112 (112)	2.5 (2.5)	2.9 (2.9)
114	2.6	3.0
116	2.7	3.1
118	2.8	3.2
120	2.9	3.3
122 (121)	3.0 (3.0)	3.4 (3.4)
124	3.1	3.5
126	3.2	3.6
128	3.3	3.7
130	3.4	3.8
132 (131)	3.5 (3.5)	3.9 (3.9)

Note: Grey shaded rows indicate treadmill speeds used in the current study. Parentheses indicate mean values in the current study.

Figure 1. Line of best fit and confidence intervals among height (cm), VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$), age-adjusted metabolic equivalents (A-AMET), and steps per minute (SPM) for the 2.5 MPH walking trial.

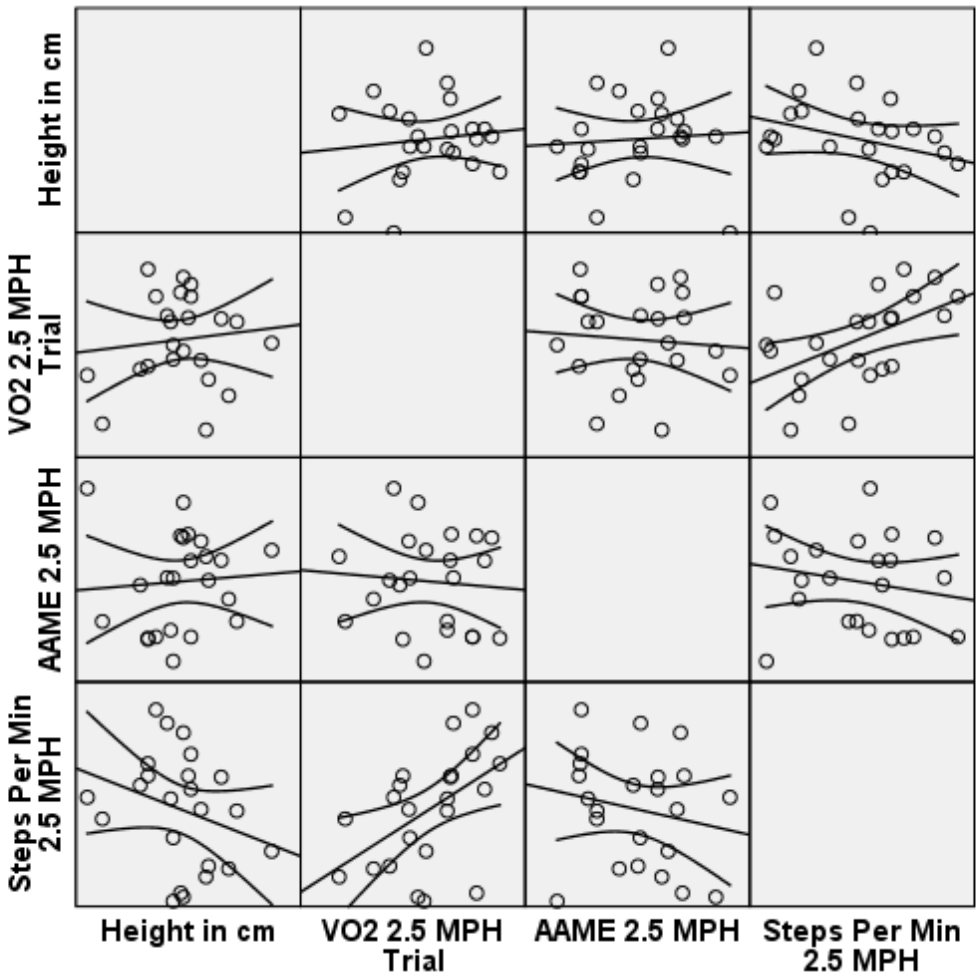


Figure 2. Line of best fit and confidence intervals among height (cm), VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$), age-adjusted metabolic equivalents (A-AME), and steps per minute (SPM) for the 3.0 MPH walking trial.

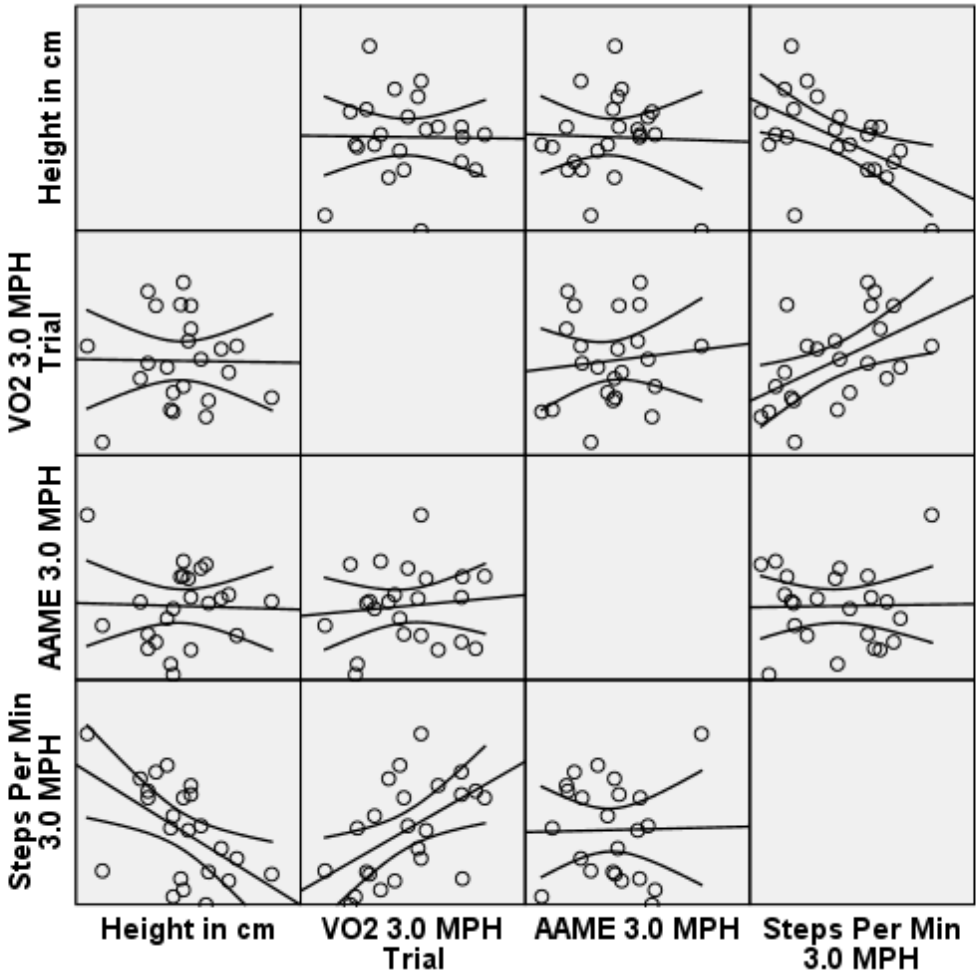
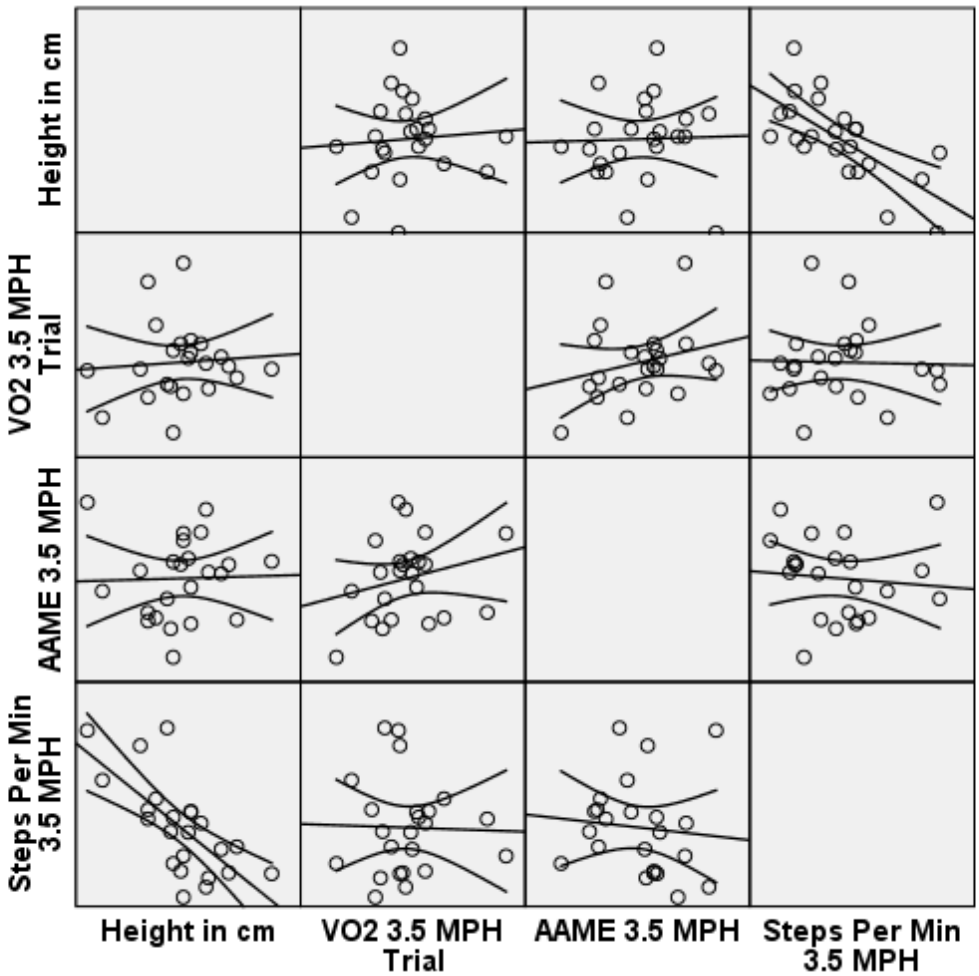


Figure 3. Line of best fit and confidence intervals among height (cm), VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$), age-adjusted metabolic equivalents (A-AME), and steps per minute (SPM) for the 3.5 MPH walking trial.



Appendix A

Introduction

Previous research has been conducted using pedometers and accelerometers to calculate step count and PA in recess, PE, and other activities. These findings have been positive in finding that these tools are capable of quantifying the amount of physical activity in such daily tasks (Barfield, Rowe, & Michael, 2004); (Stone, Rowlands, & Eston, 2009); (Strath, Bassett, Swartz, & Thompson, 2001). They also conclude that using them in conjunction with subjective measurements may give more insight into the relationship between PA and EE. There have also been positive findings that pedometers alone can be used to measure amounts of PA in the physical education setting. Scruggs' steps per minute study in PE found that 60-63 steps per minute equates to moderate PA in PE when compared to direct observation. Ultimately researchers have found that finding a step count can quantify the amount of physical activity that one completes during a set amount of time or activity (Stone, Rowlands, & Eston, 2009). However, there is no research that shows pedometers to have the ability to quantify the intensity of PA using step counts for children.

Pedometers fit unobtrusively on a belt or waistband and have been proven to be reliable and valid means of counting steps or steps per minute (SPM). However, pedometers do have their limitations, which include not being able to calculate or take into account exercise intensity, and they do not accurately record activities such as skateboarding or cycling. (Hands, Parker, & Larkin, 2006) says that this may affect the

validity of the information gathered given the episodic and variable nature of their play (Hands, Parker, & Larkin, 2006)

Extended Literature Review

Youth. The need to investigate MET levels in youth is needed because using adult MET values to predict EE in children has significant biases (Ridley & Olds, 2008). This leads to the difference in MET values of walking between adults and youth. Youth have different bodies, shorter legs, smaller lungs, etc. than do adults and those differences cause the two populations to have different EE while participating in physical activities. The review found that MET cost of walking and running increases with both age and speed of walking and running. While, on the other hand, VO2 for that same data set increases with speed but decreases with age (from preschool to adolescence. This inconsistency is one of the reasons why there is a need to look at the EE of those activities in children, further. They suggest that, "MET values should not be used to assign energy cost to children for those activities (running and walking)" (19). Developing a true compendium for youth, will allow for a better measurement of how much activity a child is getting during a particular activity. Childhood obesity is becoming more and more of a problem and the need for measuring amounts of physical activity and EE is greater then ever. This is the need that this paper is targeting. Over-estimating or under-estimating MET levels can give

out false information on EE throughout a particular activity or net activities throughout the day.

RMR and threshold for moderate activity - difference in adult and child.

MVPA is typically defined by the MET intensities that are ≥ 3 METs (http://www.cdc.gov/physicalactivity/downloads/PA_Intensity_table_2_1.pdf). Moderate activity starts at 3 METs, while vigorous activities start at 6 METs. In order to fully understand MVPA, and the METs involved, it is also important to define a MET and how it is derived. 1 MET is equal to 3.5 ml of oxygen uptake per body weight per minute (3.5 ml/kg/min). This is the standard used in terms of volume of oxygen consumed at rest (sitting quietly), or an individual's RMR. For our purposes, RMR and REE, will be used synonymously. This RMR of 3.5 ml/kg/min is based on a 70 kg adult at rest (8). From what we know about the differences in adult and youth EE, activities that are listed in the adult compendium as moderate activities may not be moderate for the pediatric age groups.

RMR for a child is different then it would be for the average adult as rest. Resting energy expenditure (REE) in children tend to be higher then adults, so, using 3.5 ml/kg/min would tend to underestimate the EE for a child during most activities in a PA compendium (12). This was also seen in their findings that, even at speeds of 2.5-3.5 mph, the children between the ages of 8-12 years old reached MET levels equivalent to moderate physical activity and over the 3 METs suggested by the adult compendium. It is therefore important to adjust for the difference in REE in the final MET calculations, another reason why a PA compendium for children would be very important to create. (8), found that using a measured RMR can correct for differences in individual EE because RMR would

be based on the individual's data rather than an estimated amount such as the 3.5 ml/kg/min standard.

Due to the differences in RMR of adults versus the RMR of youth, significant biases can arise in the computation of MET values and this type of error can cause confusion as to what the true MVPA range is. For instance, (Harrell, McMurray, et al, 2005), found that the compendium's suggestion that walking on a treadmill at 3.5 mph, yields 3.8 METs, actually underestimates the MET value that was corrected for by the true RMR collected for the individual participants. With the age adjusted VO2, they found that 8-12 year old boys and 8-11 year old girls achieved a value of 4.31 METs for walking at the 3.5 mph speed and their reached a mean VO2 of 24.6 ml/kg/min. Their data also found that the older the participant group became, the closer their RMR was to the 3.5 ml/kg/min adult standard.

Pedometers, Accelerometers, Heart Rate Monitors. There are a few other, less expensive and more portable, instruments out there that have been proven to assess amounts of PA accurately. These instruments include the accelerometers, heart rate monitors (HRM), and pedometers. Both pedometers and accelerometers can measure steps and have internal clocks to report time and this is what they use to estimate intensity. Step rate investigation has been a common trend in the measurement of youth PA, especially in schools (Scruggs, 2005 and Tudor-Locke, 02, 05, 09). These studies have mainly focused on achieving MVPA during physical education classes and thus results in lower SPM rates, due to resulting downtime in PA during class. (Scruggs, 2005), reported that third- and fourth-grade students, during chasing, fleeing, and dodging games, achieved MVPA between 58-61 SPM.

Accelerometers are small electronic, activity monitors that are commonly worn on the hip or the upper arm. They are unobtrusive, portable devices that are appropriate for measuring PA in free-living situations. The accelerometer measures the change in velocity over time, which equals acceleration. Acceleration is recorded in the uniaxial, vertical dimension, or the bi- or tri-axial dimensions which include the anterior/posterior and lateral dimensions (Robertson, Stewart-Brown, Wilcock, Oldfield, & Thorogood, 2011). Along with measuring acceleration, accelerometers can also measure step count very accurately as well. (Sallis, Buono, Roby, Carlson, & Nelson, 1990), found that accelerometers moderately to highly correlate to heart rate and oxygen consumption. Weaknesses of the accelerometer include the high cost and the reliability of the participants to wear the device appropriately. Accelerometers tend to be very expensive; sometimes hundreds of dollars and tend to underestimate children's PA compared to adult PA (Robertson, et al., 2011), and this can limit the population of a study. When studying the pediatric to adolescent age groups, it may also prove to be very difficult to get participants to wear and take off the device at appropriate times. There is also no consensus on prediction equations used to determine MVPA from accelerometers. Due to this inconsistency, reports on MVPA could be incorrect.

VO2 Analysis Overview

Oxygen analysis of oxygen uptake and energy expenditure (EE) is the gold standard. However, this type of research equipment tends to be very expensive and rather immobile. Taking measurements in everyday lifestyles would be nearly impossible and this research would need to occur in a less natural, laboratory setting. Therefore,

researchers and practitioners are in search of reliable and feasible tools that measure energy expenditure in a less expensive, less intrusive, and more convenient ways to measure EE (Barfield, Rowe, & Michael, 2004).

Oxygen analysis is used to evaluate and measure maximum oxygen consumption (VO2max) in individuals in order to assess fitness levels or the intensity that the individual is working at. We can also use the information gather from oxygen analysis to compare and compute EE at a specific point in time and during that activity.

Need to Measure EE

Metabolic equivalent (MET) intensity levels can be used to describe the EE of specific physical activities. 1 MET is equal to the resting metabolic rate of sitting quietly. (3) It is important to measure EE levels because you can therefore decipher how much energy needs to be consumed in order to support the activities of daily living. Measuring EE also helps people to understand how intense an activity is in comparison to others. Participating in different activity levels results in different EE, and a physical activity compendium has been developed to assign MET levels and EE to different activities.

Quantifying PA. Although, the terms PA and energy expenditure (EE) are not synonymous nor interchangeable, they can be used together to quantify movement (PA), age, gender, body mass, and efficiency of movement (EE) (Tudor-Locke, Williams, Reis, & Pluto, 2002). Metabolic equivalent (MET) intensity levels can be used to describe the EE of specific physical activities. For instance, 1 MET is equal to the resting metabolic rate (RMR) of sitting quietly (Ainsworth, et.al). It is important to measure EE levels

because you can therefore decipher how much energy needs to be consumed in order to support the activities of daily living. Measuring EE also helps people to understand how intense an activity is in comparison to other activities.

MET levels and EE are derived from oxygen analysis of oxygen uptake, which is the gold standard. However, this type of research equipment tends to be very expensive and rather immobile. Taking measurements in everyday lifestyles would be nearly impossible and this research would need to occur in a less natural, laboratory setting. Therefore, researchers and practitioners are in search of reliable and feasible tools that measure energy expenditure in a less expensive, less intrusive, and more convenient ways to measure EE (Barfield, Rowe, & Michael, 2004). Along with using oxygen analysis data output to assess fitness levels, we can also use the information gathered to compare and compute EE at a specific point in time and during that activity.

Adult Compendium. Participating in different activity intensities results in different EE outputs, so a physical activity compendium has been developed to assign MET levels and EE to different activities and to code such activities. Most activities of daily living are included in the compendium. Activities are grouped into major categories with specific activities listed under them. Specific to the interest of this paper, walking, happens to be a major category with different types of walking listed below it. Within the compendium, walking takes on many forms. The lowest intensity being walking very slowly on level ground (2 METs) and the highest intensity would be walking at a 5 mph pace (8 METs) (Ainsworth, Haskell, et al, 2000). This category also includes everything in between those two extremes of walking. Therefore, we see that the EE, of walking can vary through a range of intensities and MET levels. A major limitation to the compendium

is that it is a standardized classification system that doesn't take into consideration the differences within individuals. So, this means that the EE, for a given individual can be very different from the EE of another individual during the same activity. The compendium was also based on adult values. These MET intensities used in the compendium are also based somewhat on estimation rather then indirect calorimetry (Ainsworth, Haskell, et al, 2000).

Physical Activity Compendium (See walking)

A physical activity compendium has been created in order to assign EE to physical activities and to code those activities. Most activities of daily living are included in the compendium. Activities are grouped into major categories with specific activities listed under them. Specific to the interest of this paper, walking, happens to be a major category with different types of walking listed below it.

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A major limitation to the compendium is that it is a standardized classification system that doesn't take into consideration the differences within individuals. So, this means that the EE, for a given individual can be very different from the EE of another during the same activity. The compendium was also based on adult values. These MET intensities are also based somewhat on estimation rather then indirect calorimetry.

(Ainsworth, Haskell, et al, 2000) MET levels for children also need to be investigated because children have clear differences when compared to adults.

Need for Developing Youth PA Compendium

As one would expect, adults and children have different bodies, and those differences causes the two populations to have different EE while participating in physical activities. (Ridley, 2008) found that using adult MET values to predict EE in children have significant biases. The review found that MET cost of walking and running increases with both age and speed of walking and running. While, on the other hand, VO2 for that same data set increases with speed but decrease with age. This inconsistency if one of the reasons why there is a need to look at the EE of those activities in children, further. They suggest that, "MET values should not be used to assign energy cost to children for those activities (running and walking)". (Ridley, & Olds, 2008)

Developing a true compendium for the youth, will allow for a better measurement of how much activity a child is getting during a particular activity. Childhood obesity is becoming more and more of a problem and the need for measuring amounts of physical activity and EE is greater then ever. Over-estimating or under-estimating MET levels can give out false information on EE throughout a particular activity or net activities throughout the day.

Physical Activity Recommendations

Physical activity (PA) is very important to one's overall health. The World Health Organization (WHO) defines PA as, "any bodily movement produced by skeletal muscles that requires energy expenditure." (http://www.who.int/topics/physical_activity/en/) The Centers for Disease Control and Prevention (CDC) recommends that children participate in 60 minutes of PA everyday and most of this activity should be in the moderate to vigorous physical activity (MVPA) levels. Regardless of age, everyone should strive to exercise in the MVPA range. Sometimes, the challenge or obstacle to this is figuring out what this, MVPA, range means or is. Thus, if we can find a step count or range that quantifies these PA ranges, then it may be easier for people to know where they are at in terms of PA intensity.

Moderate –to-Vigorous Physical Activity (MVPA) and EE

The terms PA and EE are not synonymous nor interchangeable, but they are used together in this case to quantify movement (PA) and age, gender, body mass, and efficiency of movement (EE) (Tudor-Locke, Williams, Reis, & Pluto, 2002).

Troiano et al. (2008) analyzed accelerometer date in a sample of representative US youth (~1,800 and adolescents) from the 2003-2004 National Health and Nutritional Examination Survey (NHANES) to determine adherence to the recommended 60 minutes of MVPA per day. The results indicated that only 42% of children (6-11 yrs) obtained the recommended amount of MVPA. In contrast to that, only 8% of adolescents (12-15 yrs) obtained the recommended amounts of MVPA. They also found that people youth and adolescents tend to overestimate self-report amounts of PA. They also found that people youth and adolescents tend to overestimate self-report amounts of PA.

MVPA is typically defined by the MET intensities, ≥ 3 METs. (http://www.cdc.gov/physicalactivity/downloads/PA_Intensity_table_2_1.pdf). Moderate activity starts at 3 METs, while vigorous activities start at 6 METs. In order to fully understand MVPA, and the METs involved, it is also important to define a MET and how it is derived. 1 MET is equal to 3.5 ml of oxygen uptake per body weight per minute (3.5 ml/kg/min). This is the standard used in terms of volume of oxygen consumed at rest (sitting quietly), or an individual's resting metabolic rate (RMR). This RMR of 3.5 ml/kg/min is based on a 70 kg adult at rest. (8).

Activities that are listed in the adult compendium as moderate activities may not be moderate for the pediatric age groups. RMR for a child is different then it would be for the average adult as rest. Not only due to the clear differences in body size and type but also the fact that a child's body is constantly changing. Resting energy expenditure (REE) in children tend to be higher then adults, so, using 3.5 ml/kg/min would tend to underestimate the EE for a child during most activities in a PA compendium. (12) They found that even at speeds of 2.5-3.5 mph, the children between the ages of 8-12 years old reached MET levels equivalent to moderate physical activity and over the 3 METs suggested by the adult compendium. It is therefore important to adjust for the difference in REE and RMR in the final MET calculations, another reason why a PA compendium for children would be very important to create. (Byrne, Hills, Hunter, Weinsier, & Schutz, 2005), found that using a measured RMR can correct for differences in individual EE.

VO2 Analysis in Adults

Oxygen uptake has been studied numerous times, for many different activities, in a safe, reliable, and valid manner using oxygen analysis and different types of metabolic carts. Generally, the individual being studied reports to a laboratory setting where the study is explained to him/her and instructions are given. Information is gathered about the individual including height, weight, sex, and age. The individual is then hooked up to the analyzer and performs the specified activity. The analyzer goes to work and outputs a set of data regarding the individual's oxygen uptake.

VO2 Analysis in Youth (Differences between Adults and Youth)

VO2 analysis testing in general is fairly similar to adults. However, there are a few differences that are very important and need to be addressed. The Committee on Atherosclerosis and Hypertension in Children, Council on Cardiovascular Disease in the Young, and the American Heart Association came out with the "Guidelines for exercise testing in the pediatric age group" to lay out a foundation for such testing.

First and foremost, the investigator must ensure that the proper instruments are being used and that the equipment fits the subjects. This is very important in the pediatric age groups because their body size and type tends to differ greatly from the adult population that is typically used for testing in exercise physiology laboratories. It is essential to check that the mouthpiece size fits appropriately and that the nose clip and headgear fit comfortably without moving around.

Similar to performing exercise testing on adults, especially during maximal tests, it is very important to clearly define the ending of the test criteria. Attention needs to be paid to inability of subject to perform task, VO2 plateau, predicted maximal heart rate (HR),

and maximal respiratory exchange ratio (RER) (Karila, de Blic, Waernessyckle, Benoist, Scheinmann, 2001). Perceived exertion and HR used in conjunction can also be a good indicator of fatigue. If instructions are clearly given and subject population can understand and comprehend them, the 6-20-point Borg scale may be used to assess perceived exertion. (Washington, Bricker, et al, 1994)

There are also a few general principles to keep in mind while doing pediatric exercise testing. Obviously, the first requirement is that there needs to be a reason for doing the testing. If there is no reason then it shouldn't be done. The physical, testing, environment must be safe and kept in proper conditions. Safety always comes first in any testing setting, especially in the laboratory because it is typically a new setting for most participants. Consent must be obtained before testing begins. The participants need to have a clear understanding of what will be done and the reason why they are being tested. Also, any contraindications to exercise must be appropriately recorded, monitored, and managed correctly to ensure the safety of participants.

The ACSM has also put out a set of similar guidelines and precautions to exercise testing for children. In addition to the aforementioned guidelines, the ACSM suggests that the protocol used should have stages that are approximately 2-3 minutes in length. Also, the test protocol should only be between 8-12 minutes. A child's attention span and adjustment to being in a different setting are different then an adults so adjustments need to be made. The ACSM also say that it helps to have child friendly and appropriate pictures on the walls and a friendly an children loving investigator that is prepared to encourage the participation of the subjects. (Riner & Sabath, 2011)

Other Instruments to Measure MVPA accurately

Accelerometers

One of the most popular instruments to do so, currently, is the accelerometer. Accelerometers are small electronic, activity monitors that are commonly worn on the hip or the upper arm. They are unobtrusive, portable devices that are appropriate for measuring PA in free-living situations. The accelerometer measures the change in velocity over time, which equals acceleration. Acceleration is recorded in the uniaxial, vertical dimension, or the bi- or tri-axial dimensions which include the anterior/posterior and lateral dimensions (Robertson, Stewart-Brown, Wilcock, Oldfield, & Thorogood, 2011). Along with measuring acceleration, accelerometers can also measure step count very accurately as well.

As in any instrument, there are strengths and weaknesses to the accelerometer. Strengths of this device include that it is non-invasive, it is proven to be a valid and reliable instrument to measure body movements, it is able to provide information on intensity, duration, and time of activity, and it is able to be used in the laboratory or free-living situations. (Sallis, Buono, Roby, Carlson, & Nelson, 1990), found that accelerometers moderately to highly correlate to heart rate and oxygen consumption. This means that it is comparable to the gold standard of oxygen analysis and EE measurements.

Weaknesses of the accelerometer include the high cost and the reliability of the participants to wear the device appropriately. Accelerometers tend to be very expensive; sometimes hundreds of dollars, and this can limit the population of a study. When studying the pediatric to adolescent age groups, it may also prove to be very difficult to get participants to wear and take off the device at appropriate times. (Robertson, Stewart-

Brown, Wilcock, Oldfield, & Thorogood, 2011), also found that accelerometers may actually underestimate children's PA.

Heart Rate Monitors

Heart rate monitors (HRM) have been very popular in the PA research setting for many years. The most common monitors in the research setting, because of their accuracy, require 2 devices to be worn on the body. The first, is the transmitter, worn around the chest of the participant, must be a little moist when first put on, and must have direct contact with the skin. The second device is the monitor, which is typically worn around the wrist, similar to a watch. The transmitter registers the electrical impulses from the heart and sends that directly, and continuously to the monitor. Data is outputted in beats per minute and can be collected instantly or downloaded at another time. HRM can also be used with some oxygen analyzers and can transmit the HR data to such analyzers.

There have been many studies done on HRM, showing them to be accurate and also linking them with high correlation values to other physiological monitors including oxygen analysis and electrocardiograms. (Bassett, 2000), showed that there is a linear relationship between HR and VO2, which allows researchers to predict VO2 across various exercise intensities.

HRM also have its complications when it comes to usage in the research setting. Costs for HRM are relatively expensive, often running in the hundreds of dollars. This is a major limitation to the usage of these monitors. Also, there are many variables that affect the results of HRM such as the time of day, length of wear, anxiety, stress, and variations of the HRM , amongst other variables (Rice, & Howell, 2000).

Pedometers

Previous research has been conducted using pedometers and accelerometers to calculate step count and PA in recess, PE, and other activities. These findings have been positive in finding that these tools are capable of quantifying the amount of physical activity in such daily tasks(Barfield, Rowe, & Michael, 2004); (Stone, Rowlands, & Eston, 2009); (Strath, Bassett, Swartz, & Thompson, 2001). According to (Tudor-Locke, Williams, Reis, & Pluto, 2002), pedometers found that pedometers are a valid instrument to use in research and in practice to assess PA. They also conclude that using them in conjunction with subjective measurements may give more insight into the relationship between PA and EE.

There have also been positive findings that pedometers alone can be used to measure amounts of PA in the physical education setting. Ultimately researchers have found that finding a step count can quantify the amount of physical activity that one completes during a set amount of time or activity (Stone, Rowlands, & Eston, 2009). However, there is no research that shows pedometers to have the ability to quantify the intensity of PA using step counts for children.

Pedometers fit unobtrusively on a belt or waistband and have been proven to be reliable and valid means of counting steps or steps per minute (SPM). However, pedometers do have their limitations, which include not being able to calculate or take into account exercise intensity, and they do not accurately record activities such as skateboarding or cycling. (Hands, Parker, & Larkin, 2006) says that this may affect the

validity of the information gathered given the episodic and variable nature of their play (Hands, Parker, & Larkin, 2006) For this study, we are particularly interested in the pedometers because of their function and the fact that we will be counting steps per minute in our study.

Appendix B

Parent Consent Form

STEP RATE RECOMMENDATIONS FOR MODERATE ACTIVITY WALKING IN CHILDREN

Department of Kinesiology and Rehabilitation Science

WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of the study is to determine the walking intensity that constitutes moderate to vigorous physical activity (MVPA) in children using step count and oxygen analysis. The goal of this study is to determine the number of steps per minute required to achieve moderate exercise intensity in youth. The majority of children's daily physical activity usually comes from walking, and therefore it is important to investigate how walking can help achieve the recommended 60 minutes of daily moderate to vigorous physical activity.

In this study, about 30 elementary and middle school students at the University Lab School and a local soccer club will have their walking energy expenditure measured. We will collect energy expenditure data with the use of two trained assessors who will be counting steps while your child is walking on a treadmill and using and an oxygen analyzer during the Fall 2011 and Spring 2012 semesters. Oxygen analysis is a safe and highly reliable tool in the assessment of physical activity. (See picture below).

QuickTime™ and a decompressor are needed to see this picture.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

- There will be two testing days involved and the sessions in total will take no longer than 40 minutes:
  - All sessions will take place at the University of Hawaii at Manoa's exercise laboratory, located at the Stan Sheriff Building, during regularly scheduled physical education classes. Or on the weekends for the HYSA (Hawaii Youth Soccer Association) participants.
  - Day 1:
    - Introduction and familiarization with treadmill and will include practice time on the treadmill.
    - I will also measure height (cm) and weight (kg) with participants clothed and privately with another research assistant present. This information will

be collected to help determine the relationship between walking steps and different sized children.

- Day 2:
  - Participants will be required to complete a six-hour fast prior to testing. Only water may be consumed during the fasting period.
  - Assessing will also include the collection of resting energy expenditure (sitting quietly and relaxed for 15 minutes), and walking on the treadmill for 11 minutes: a self-selected warm-up speed, followed by 3 trials of 2.5, 3, and 3.5 mph respectively.
    - Assessments will require participants to be hooked up to an oxygen analyzer through the use of the mouthpiece. During the exercise portion, the participant will also be walking on a treadmill at speeds that will not require any running.

WHAT IS THE PURPOSE OF THIS FORM? This consent form provides you the information that you will need to help decide whether or not **your child** can should in the study or not. You may ask any questions about the research, the possible risks and benefits, the rights of your child as a volunteer, and anything else that may not be clear. When all your questions have been answered, you can decide if you want your child to be in this study or not.

WHAT ARE THE RISKS OF THIS STUDY?

- There are minimal, if any risks involved with participation in the study:
  - The treadmill - The treadmill will be inspected for any safety hazards and it will be equipped with handrails. Each participant will also be given an opportunity to familiarize him/herself with the treadmill and will also be able to practice walking at the slowest and fastest testing speeds (no faster than a brisk walk).
  - Utilization of a mouthpiece - The oxygen analyzer and mouthpiece will be sterilized properly after each use. Care will be taken as to ensure comfort and that the mouthpiece fits comfortably.
  - Exercise testing – Participants will only walk at the 3 speeds for 2 minutes each as recommended by the American Heart Association and the American College of Sports Medicine.
  - Privacy - Height and weight will be measured fully clothed with a male and female assistant present. Data is collected in this way because we are concerned about protecting the body image of children. Research has also determined that height and weight measurements do not affect children's body image.

WHAT ARE THE BENEFITS OF THIS STUDY?

Short Term:

- Students will learn about and experience exercising on a treadmill.
- Gain knowledge of different ways that physical activity can be assessed, in addition to what they learn in Physical Education Class.

Long Term:

- The results of this study may influence moderate physical activity recommendations for youth to better determine the health and wellness benefits of physical activity for youth.

WHO WILL SEE THE INFORMATION I GIVE?

The information gathered during this research study will be kept confidential to the extent permitted by law. To help protect the participants' confidentiality, only researchers participating in the research study will be able to identify participants with their assessments. For publication/presentation, no identifiable information (i.e., names) will be included. All data will reside in one computer, which is password-protected to ensure limited access to any confidential information.

DO I HAVE A CHOICE TO BE IN THIS STUDY?

If you and your child decide to take part in the study, it should be because your child really wants to volunteer. Your child will not lose any benefits or rights your child would normally have if your child chooses not to volunteer. Your child may stop at any time during the study and will still keep the benefits and rights your child had before volunteering. If you or your child decides to not take part in this study, the decision will have no effect on the quality of education, care, services, etc. your child receives. Your child will not be treated differently if you or your child decides to stop participating in the study. If your child chooses to withdraw from this study before it ends, the researchers may keep information collected about your child and this information may be included in study reports.

WHAT IF I HAVE QUESTIONS?

If you have questions about this research project, please contact:

Charles F. Morgan, Ph.D.
Associate Professor
Department of Kinesiology & Rehabilitation Science
1337 Lower Campus Rd. PE/A Complex 216
Honolulu, HI 96822

Allison Tsuchida
Masters Student Dept. of Kinesiology and Rehab Science
1337 Lower Campus Rd.
PE/A Complex 216
Honolulu, HI 96822
(808) 358-0754

The UH Committee on Human Studies at (808) 956-5007, or uhirb@hawaii.edu

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to let your child take part in this study. You will receive a copy of this form.

Parent/Guardian or Legally Authorized Representative's Name and Relationship to Participant

Child's Name: _____

Child's DOB (MM/DD/YYYY): _____ / _____ / _____

Name of Parent/Guardian Legally Authorized Representative (printed):

_____

Relationship to Participant (printed): _____

Signature of Parent/Guardian Legally Authorized Representative:

_____

Appendix C

Child Assent Form

STEP RATE RECOMMENDATIONS FOR MODERATE ACTIVITY WALKING IN CHILDREN

Department of Kinesiology and Rehabilitation Science

The Purpose?

This is a study to determine the energy you use when you walk.

What will be involved?

I am going to see how tall you are, how long your leg lengths are, and how much you weigh, privately in the UH exercise lab. On one day, you will come in to the exercise lab and we will see how much energy you use when you are resting and then we will see how much energy you use when you walk at your usual walking speed and 3 other walking speeds. In order to do this, we will count how many steps you take during each stage and you will also be hooked up to an oxygen analyzer by the use of a small mouthpiece.

QuickTime™ and a decompressor are needed to see this picture.

What do I do?

All you need to do is not eat anything for 6 hours before your test (only drinking water is allowed), sit and rest quietly in a dimly lit room for 15 minutes, and then walk on a treadmill for a total of 11 minutes. You will select a speed to warm up at that feels like the speed you normally walk at. Then you will keep walking for 3 additional stages as the treadmill gets a little faster every 3 minutes. You will never have to run or jog. You will be notified when the speed will increase so you will not be surprised. During the test you will be hooked up to an oxygen analyzer by a mouthpiece, supported by a piece of headgear to keep it in place. You will be breathing out of the mouthpiece through your mouth only during the whole test.

Do I have to do it?

No you do not have to participate, only if you want to. If you wish to stop at anytime, you can.

I WANT TO PARTICIPATE!

If you want to be in this study, please print and sign your name.

_____

(Your first and last name – printed)

_____ _____

(Sign your first and last name) **(Date)**

Allison Tsuchida PH: (808) 358-0754 artsuchi@hawaii.edu

Charles F. Morgan, Ph.D. PH: (808) 956-3804 morganc@hawaii.edu

Appendix D

General Protocal Instructions

Good morning. Welcome to the University of Hawaii Exercise Laboratory.

This morning, we will be gathering a few sets of data from you.

First, I will be measuring your height.

Next, I will record your weight.

After we take down those measurements, I will be ask you to please lay down on this padded table and relax for 15 minutes. Please feel free to find a comfortable postion on your back but do not fall asleep. We will equip you with and hook you up to a headgear that includes a mouthpiece that will be connected to the oxygen analyzer that you see here. You may breath normally through your mouth but I will be using this noseclip to restrict you from breathing through your nose.

When the 15 minutes is complete, we will come and take the mouthpiece and nose clip off so that you can breath normally for a minute or two. You may also have a sip of water if you want to.

We will then head over to the treadmill. Prior to the treadmill testing, you will again be hooked up the the oxygen analyzer by the use of the supportive headgear and mouthpiece. You will start on the treadmill in the off position. I will give you a countdown of, “3, 2, 1, go”. At this point, the treadmill will begin to move and I will be slowly increasing the speed. When you feel like you are at the speed that you normally walk at, for instance, during school, please give me a “thumbs up”. At this time, you will hear a “go” which will signal to the recorders the start of the two minute warm-up.

At the end of the warm-up stage, you will hear a countdown, “5, 4, 3, 2, 1, OK”, this will signal to the recorders that the stage has ended. You will then be informed that the treadmill speed will be set at the first speed of 2.5 mph. It may be a slight increase in speed. Please keep walking throughout the test. Again, you will hear a, “3, 2, 1, go”. This will again signal the start of the first stage. At the beginning of the third minute, you will be asked to give your rate of perceived exertion. “How hard you feel that you are working.” (See RPE instructions) After three minutes, you will hear another countdown, “5, 4, 3, 2, 1, OK”, this will signal to the recorders that the stage has ended.

This process will be repeated 2 more times. The speed will increase by half a mile per hour. Please keep walking throughout the test. I will check on you and support you throughout the test. If at any time during the test you feel as though you want to quit and

stop the test, please give me a thumbs down and put both hands on the front bar of the treadmill. I will stop the treadmill immediately.

After the third stage has ended, you will hear a, “5, 4, 3, 2, 1, Done”. This means that the test is over but please keep walking as I end the test, the treadmill will slow down to a stop for you. When the treadmill has stopped completely, I will notify you that it is safe to relax. The headgear and mouthpiece will be removed for you.

The test will then be completed.

APPENDIX E

UNIVERSITY OF HAWAII AT MANOA
DEPARTMENT OF KINESIOLOGY AND LEISURE SCIENCE
MEDICAL HISTORY FORM

Please complete this medical history form for your child and return with the consent form.

Child's Name _____ Child's Date of Birth _____

Address_____

_____

Home Phone _____ Other Phone_____

Emergency Contact Person

Name _____ Relationship_____

Home Phone _____ Work/Cell Phone_____

Hospital Preference _____

Doctor Preference _____Phone _____

Please identify any condition that your child may have or had that might restrict his/her participation in physical activity. If you answer yes to any of the following, please describe the proper aid requirements on the next page.

A. General Conditions

1. Fainting Spells Yes No Past Present
2. Headaches Yes No Past Present
3. Convulsions/epilepsy Yes No Past Present
4. Asthma Yes No Past Present
5. High Blood Pressure Yes No Past Present
6. Kidney Problems Yes No Past Present
7. Intestinal Disorder Yes No Past Present
8. Hernia Yes No Past Present
9. Diabetes Yes No Past Present
10. Heart Disease/Disorder Yes No Past Present
11. Dental plate Yes No Past Present
12. Poor Vision Yes No Past Present
13. Poor Hearing Yes No Past Present

B. Injuries

1. Toes Yes No Past Present
2. Feet Yes No Past Present
3. Ankles Yes No Past Present
4. Lower Legs Yes No Past Present
5. Knees Yes No Past Present
6. Thighs Yes No Past Present
7. Hips Yes No Past Present
8. Lower Back Yes No Past Present
9. Upper Back Yes No Past Present
10. Ribs Yes No Past Present
11. Abdomen Yes No Past Present
12. Chest Yes No Past Present
13. Neck Yes No Past Present

14. Skin Disorder Yes No Past Present
15. Allergies Yes No Past Present
Specific_____Past Present
_____

16. Joint Dislocation Or separations Yes No
Specify_____Past Present

17. Other
_____
_____Past Present

14. Fingers Yes No Past Present
15. Hands Yes No Past Present
16. Wrists Yes No Past Present
17. Forearms Yes No Past Present
18. Elbows Yes No Past Present
19. Upper Arms Yes No Past Present
20. Shoulders Yes No Past Present
21. Head Yes No Past Present
Specify_____
_____ Past Present

22. Others _____
_____ Past Present

PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR ABILITY FOR YOUR CHILD

Does he/she have any predisposing cardiorespiratory or cardiovascular conditions that the researcher should be aware of?

No_____ Yes_____(if so, explain)

Does he/she have any other medical problems that the researcher should be aware of?

No_____ Yes_____(if so, explain)

Has your child ever undergone any type of surgery?

No_____ Yes_____(if so, explain)

_____ Date_____
Parent/Guardian Signature

Appendix F

Recruitment Form

STEP RATE RECOMMENDATIONS FOR MODERATE ACTIVITY WALKING IN CHILDREN

Department of Kinesiology and Rehabilitation Science

WHAT IS THE PURPOSE OF THIS STUDY?

The majority of children's daily physical activity usually comes from walking. So, it becomes even more important to investigate how fast an individual should be walking in order to achieve the recommended 60 minutes of daily moderate to vigorous physical activity. Oxygen analysis is a safe and highly reliable tool in the assessment of physical activity.

In this study, about **30 elementary and middle school students** at the University Lab School and a local soccer club will have their walking energy expenditure measured. I will collect energy expenditure data with the use of two trained assessors who will be counting steps and an oxygen analyzer during the Fall 2011 and the Spring 2012 semesters. The purpose of the study is to determine the steps per minute (SPM) threshold that constitutes moderate to vigorous physical activity (MVPA) in children using step count and oxygen analysis. The goal of this measurement study is to determine the number of SPM required to achieve moderate exercise intensity in youth.

QuickTime™ and a decompressor are needed to see this picture.

WHAT ARE THE BENEFITS OF THIS STUDY?

Short Term:

- Students will learn about and experience exercising on a treadmill.
- Students will gain knowledge of different ways that physical activity can be assessed, in addition to what they learn in Physical Education Class.

Long Term:

- The results of this study may influence moderate physical activity recommendations for youth to better determine the health and wellness benefits of physical activity for youth.

WHAT IF I HAVE QUESTIONS?

If you have questions about this research project, please contact:

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