Research Square

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Energy cost of selected training and non-training activities of 10-17-year-old Indian athletes: a cross-sectional study

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Abstract

Background Factorial approach using activity recording and metabolic equivalents (METs) is most often used to compute 24-hr energy expenditure pattern among athletes. However, the existing compendiums for energy cost of physical activities were developed on non-athlete adults or children. Therefore, the present study aimed to determine the energy cost of selected physical activities of junior athletes. Further, the suitability of existing compendiums among Indian junior athletes were assessed.

Methods In this cross-sectional study, 91 Indian junior athletes (Boys: 45 and Girls: 46) from athletics, soccer and weightlifting events, were monitored for their activity pattern (Rest, Training and non-training activities) and volume of oxygen consumed (ml/kg/min) using portable metabolic analyser. Sex and/or age-specific differences were determined using ANOVA and measured METs were compared with Compendium of Physical Activity (*CPA)* and Compendium of Energy Expenditure for Youth (*CEEY*) using single-sample t-test.

Results The energy cost and METs showed sex-specific differences with a strong association between measured Heart rate and METs. The measured METs covered a range of physical activities from 0.7 (Resting Metabolic Rate; RMR) to 10.8 (shuttle run). On comparison with compendium, measured METs for RMR was significantly higher in junior athletes, except in soccer players (junior boys and girls) having lower METs. For majority of the activities, measured METs were comparable with adult compendium (CPA), than children's (CEEY).

Conclusions Thus, the METs determined on Indian junior athletes adds to the existing database and is useful to evaluate energy expenditure. Further, in the absence of athlete-specific compendium, CPA seems prudent for determining energy needs.

Introduction

Determining energy expenditure of youth and adolescents is crucial and a long-standing objective to accurately ascertain the nutritional demands and fuelling strategies during this growth period. To arrive at the total energy expenditure of adolescents from self-reported or directly observed physical activity records, it is important to generate a compendium constituting the energy cost of activities carried out by the adolescent group. The Compendium of Energy Expenditure for Youth (CEEY) [1] was developed with this objective. However, this compendium has only 35% activities which were measured directly on youth aged 6–18 years using an indirect calorimetry and the remaining were extrapolated from adult counterparts after correcting for resting energy expenditure. Ridley and Olds [2] suggested the use of adult Metabolic Equivalents (METs), corrected for Resting metabolic Rate (RMR) of children as the best technique to assign energy expenditure for children in the absence of measured values. However, even the Resting metabolic rate among children has been determined using prediction equations in some studies rather than direct measurement [3,4], which might not be specific for the Indian context. To date a comprehensive compendium has not been established for youth, exhibiting a need for generating data on energy cost of activities.

In case of adolescent athletes, time spent in structured physical activity and physical activity energy expenditure is higher compared to their non-athletic counterparts, however, most of the compendiums developed so far [1,5–7] or research carried out on children or adolescents have focussed on non-athletic

population[8–15] and activities of daily living, including certain types of structured and unstructured physical activity [8]. Trained athletes tend to be physiologically efficient than the normal healthy adolescents with variation in RMR and energy cost of activities as a result of improved lean to fat ratio [16]. Therefore, RMR, energy cost of physical activities and METs specific for children and/or adolescent athletes will be useful in arriving at individualised energy requirements.

Considering the dearth of information on METs and energy cost of activities among adolescent athletes and the CEEY being more suitable for expressing energy expenditure of sedentary to light activities, [3] it seemed prudent to determine METs for a range of activities from sedentary to higher intensity among junior athletes in the Indian context. Therefore, this study aimed to determine RMR and energy cost of activities among Indian junior athletes aged 10–17 years participating in athletics, soccer and weightlifting events, and to arrive at the event-specific METs from real-time situations. This study hypothesised that the METs for physical activities carried out by junior athletes would differ from the METs in prevailing compendiums [1,5].

Materials And Methods

Experimental approach

In this cross-sectional observation study, junior athletes were recruited and their activity was monitored using activity records. The indirect calorimetry was used to determine resting metabolic rate and energy cost of selected training and non-training activities in real-time field settings. This study was part of a project and was approved by the Institutional Ethics Committee and has followed the Declaration of Helsinki. The written informed consents were obtained from parents of participants prior to the study. It was conducted in Telangana State Sports School, Hyderabad in the year 2014. The Abstract of this study was published in the proceedings of the 24th Annual Congress of European College of Sport Science [17].

Study Participants

Athletes aged 10-17 years (n = 91; Boys: 45 and Girl: 46) participating in three events (Athletics, Weightlifting and Soccer) being trained in the sole government-owned sports school for junior/adolescent athletes in the South Indian State of Telangana were recruited for the study. Athlete were from within the state, and majority of them come from rural areas and difficult homes as reported by the coaches [18]. Although a sample size was calculated based on the energy expenditure pattern [19], however, over and above, all athletes meeting the inclusion criteria of being apparently healthy and training for over 3 years with 24 hours training per week were recruited. A total of 117 athletes participating in athletics, weightlifting and soccer events were screened, out of which 21 athletes did not meet the age-criteria of the study and 5 athletes left the school in-between data collection (depicted in Figure 1).

Data Collection

The participants for this study were selected based on convenience sampling from a residential sports training facility. This sampling technique seemed prudent considering that this was the sole professional sports training centre within the state, particularly for the events selected and the junior athletes with similar competition level, exhibiting uniform food habits, activities, training protocol etc. could be recruited. Initially, necessary approvals were taken from the Director of the sports school, the coaches and the teaching faculty in their school, following

which junior athletes in selected events were recruited and explained about the study and their level of involvement. Data related to energy cost of activities were collected mainly during their training sessions, both in the morning and evening. It was collected in the order of warm up, main training and cool down activities in the field setting for the real time situational assessment.

Physiological Characteristics

Indirect calorimetry (Oxycon mobile, VIASYS Healthcare, Germany) was used to measure cardiopulmonary variables and to determine the energy cost of activities. It measures real time breath-by-breath respiratory gas exchange through an electrochemical sensor and data are transmitted telemetrically and recorded on a personal computer under free-living conditions. During exercise, the battery operated oxycon mobile can be comfortably strapped to the chest or the back of an athlete and allows continuous data sampling. Gas and Volume calibrations are carried out every day before starting the measurement. Heart rates were recorded simultaneously for all the activities using a POLAR-PE-3000 (Finland) interfaced with the oxycon mobile.

Oxycon mobile has been used as a criterion method in many validation studies among adults and young individuals [20]. It showed 2-7 % variation against Douglas bag, across activities with different metabolic rates [21]. Compher, *et al.* [22] suggested that a CV of < 10 % gave accurate reading for RMR and the intra-individual CV of oxycon mobile for oxygen consumption at resting condition among the study participants was 2.4%.

Determination of Energy cost and Metabolic Equivalents (MET(s))

Standard procedure was followed for RMR measurement as described by Compher, Frankenfield, Keim, Roth-Yousey and Group [22] and the protocol for measurement of RMR and training activities has been detailed by the authors elsewhere [23], [24]. Every activity was measured after giving due acclimatisation phase and upon reaching steady state in terms of heart rate and oxygen consumption. The data collected was also screened for over and under-breathing by the participants with pruning of such values.

Absolute volume of oxygen (VO_2) measured using the indirect calorimetry was used for calculating the energy cost of activities and to arrive at the metabolic equivalents (METs) for various training and non-training activities. METs for training and non-training activities were calculated by dividing volume of oxygen (VO_2) consumed for a given activity by volume of oxygen consumed for RMR.

Description of the training and non-training activities

The measured training and non-training activities and training load are listed in Table 1 (a and b). Among training activities, warm up activities like warm up jogging, warm up exercise, striding and shuttle run were measured for athletics and soccer events. Technical warm up was carried out by soccer players involving side, front and back run, high jumps, roll backs etc. Step conditioning is a set of exercise carried on a staircase such as zig-zag run, crocodile walk, jumping, skipping etc. Among weight training activities, in Box jump, the athlete jumps up and down on a Harvard step test box, while in box jump with weight, they carry weight and step up on the Harvard step test box. Only soccer players were classified as senior (Sr.) and junior (Jr.) boys because the training activities were performed differently with different intensity.

Description of the selected Compendiums

Research studies on athletes utilise two popular compendiums [1,5] to arrive at the individual energy requirement and therefore, the activity METs in these compendiums were compared with that of the measured METs for a given activity (Table 1a and 1b).

Adult Compendium of Physical Activities (CPA)

This was developed by Ainsworth, Haskell, Whitt, Irwin, Swartz, Strath, O Brien, Bassett, Schmitz and Emplaincourt [5] for use among adult population and the RMR in this compendium is 0.9 MET. Ridley and Olds [2] reported that this compendium was most accurate to assign energy cost for children in 51 non-locomotor activities as compared to FAO/WHO/UNU [6] and Torun [25]. However, for activities involving walking and running, the compendium was found to have higher errors.

Compendium of energy expenditure for Youth (CEEY)

This compendium developed by Ridley, Ainsworth and Olds [1] was modelled after the CPA with 35 percent of activities directly measured on children aged 6 - 18 years and remaining activities derived from CPA after correcting for RMR.

Statistical Analyses

Statistical analyses were done using IBM SPSS (version 19.0; Armonk, NY). Normality for sex-specific physical characteristics (body mass, fat percent and fat-free mass) and total energy expenditure assessed using Shapiro-Wilk Test exhibited a normal distribution. ANOVA was used to determine differences in VO_2 (ml/kg/min), Heart Rate (beats/min), Energy cost of activities (kcal/min) and METs across sex & event and/or age-groups. Participants missing data pertaining to energy cost of training or non-training activities within an event was mainly due to that activity not performed by an individual athlete in the activity recording and was retained, accordingly, represented as “n” within tables or figures. The comparison across age-groups in soccer may be seen with caution, considering the smaller sample size in the Jr. group, however, they included all the available players within the study setting. The measured METs were compared with METs from existing compendium using the single-sample t-test. The GraphPad Software (San Diego, CA) was used to run unpaired t-test and single-sample t-test to compare the measured METs in this study with the METs from existing literature. Significance was set at a *P-value <0.05*.

Results

Participant Characteristics

The sample for this study were 15 junior athletic boys (10-16yrs; Body Mass (BM): 50.8 (5.74) kg; Height: 166.7 (5.23) cm; Body fat (BF%): 12.9 (1.67)) and 15 Girls (10-16 yrs; BM: 44.9 (3.85) kg, Height: 155.3 (4.09) cm; BF%: 21.5 (2.45)).

For soccer, it was 14 Senior (Sr.) boys (11-16yrs; BM: 52.6 (6.88) kg; Height: 166.7 (4.06) cm; BF%: 13.5 (3.20)), 7 Junior (Jr.) boys (10 yrs; BM: 32.9 (2.96) kg; Height: 146.3 (6.17) cm; BF%: 12.9 (1.91)) and 19 Girls (10-16 yrs; BM: 45.1 (6.58) kg; Height: 153.6 (4.64) cm; BF%: 23.8 (3.46)).

For Weightlifting, it was 9 boys (11-17yrs; BM: 53.4 (5.65) kg; Height: 162.3 (4.53) cm; BF%: 16.0 (2.67) and 12 Girls (11-17 yrs; BM: 51.7 (6.69) kg; Height: 153.2 (4.17) cm; BF%: 25.5 (2.52))

Energy cost of training and non-training activities

Comparison of volume of oxygen consumed (VO_2 ml/kg/min), heart rate, energy cost per minute and METs of selected non-training activities among junior athletes across sex are presented in Table 2. Among the total group (Boys=45 and Girls=46), the VO_2 (ml/kg/min) and Energy cost of RMR, sitting and standing were significantly lower among girls compared to boys, while it was similar for walking. For standing, heart rate and METs were similar across sex, whereas, for RMR and walking it was different (*P-value<0.01*). While considering the events independently, the girls in athletics group, exhibited similar VO_2 (ml/kg/min) for RMR, sitting and standing and a significantly higher heart rate as compared to boys. On the contrary, METs were different for RMR and standing across sex, while being similar for sitting and walking. Among soccer and weightlifting group, the Heart rates and METs of sitting, standing and walking were similar across sex, albeit not RMR. Thus, irrespective of the event, RMR showed significant difference across sex, with girls exhibiting lower RMR than boys.

Similarly, the energy cost of training activities was compared across sex (Table 3). Among warm up activities in athletics and soccer, the warm up jogging showed no significant difference in MET values, irrespective of sex and event (*P-value*: Boys=0.612 and Girls=0.068). However, in athletics group, heart rates were not similar across sex for warm up jogging and exercise, with girls having higher heart rate than boys. While, soccer players showed no significant difference in heart rate and MET values for all warm up activities across sex (i.e. senior boys versus girls) and across age-groups (i.e. senior versus junior boys), except for technical warm up.

Even, the METs for main training activities like weight training and step conditioning among soccer players showed no significant difference across sex, while energy cost per minute showed significant sex differences. METs for Interspersed rest (sitting, standing and walking) were significantly different between senior soccer boys and girls, while junior boys and girls showed similar METs for interspersed standing and sitting (Table 3). Girls exhibited significantly lower METs for cool down stretching exercise as compared to junior boys whereas, senior boys and girls did not show a significant difference in VO_2 (ml/kg/min), heart rate and MET. Most of the differences in heart rates across sex for training activities, corroborated with differences in METs, except for warm up jogging carried out by athletics group, weight training and interspersed walking carried out by soccer players.

Among weight training activities, the senior boys and girls exhibited similar METs for all activities, except bench press and leg curl (Table 4). Even Heart rates for all weight training activities, except leg curl, were similar between senior boys and girls. Across senior versus junior boys, VO_2 (ml/kg/min), heart rate and MET values for all weight training activities were not significantly different, except wrist curl (*P-value<0.05*). Further, for leg curl, the VO_2 (ml/kg/min) were not significantly different across senior boys, junior boys and girls, though heart rate differed. Girls showed significantly lower VO_2 (ml/kg/min) for wrist curl, bench press and box jump, compared to either senior or junior boys. Girls also exhibited significantly lower MET values for wrist curl and box jump as compared to junior boys. Thus, for all weight training activities, except bench press, differences in heart rates across sex (i.e. senior boys versus girls) was accompanied by differences in METs across sex.

Comparison of Measured METs versus METs from Compendium

Comparison of METs for light activities from existing compendium (CPA and CEEY) with METs measured among junior athletes are presented in Figure 2. Among athletics and weightlifting group, the METs for RMR were significantly higher than Compendium METs (CPA and CEEY), irrespective of sex. The METs for sitting quiet was significantly lower than CEEY METs among junior athletes, except for the 10-year-old junior soccer players showing similar METs. On comparing with CPA, sitting MET was significantly higher among athletics group, while, soccer (senior boys and girls) and weightlifting group showed similarity. Irrespective of event and sex, the standing MET of junior athletes were significantly lower than CPA and CEEY. While, for self-paced walking the measured METs were comparable to CPA MET among junior athletes, except for weightlifting boys showing lower METs. Whereas, CEEY MET for walking was significantly higher than most of the junior athletes, except soccer girls. Thus, junior athletes, irrespective of the event, seemed to show differences in measured METs for RMR as compared to Compendium METs. Further, measured METs for light activities showed more similarity with METs from CPA as compared to CEEY.

Among training activities, the METs measured for warm up jogging was similar to METs in both compendiums (CPA and CEEY). For warm up exercise, only boys in athletics group showed similar METs as compendiums. For shuttle run, soccer players showed similar METs as CPA. Soccer players also showed significantly higher METs for cool down stretching exercise, crunches, push-ups, leg press, leg curl, shoulder press and shoulder pull compared to METs from existing compendium (Figure 3).

Discussion

Factorial approach of determining energy expenditure pattern is dependent on the time spent in various types of activities and the energy cost of those activities. Physical training time, volume and intensity is in turn dependent on age, type of sport and the phase of training [26]. In this study athletes were in the adolescent stage with majority of them involved in sport-specific training for more than two years, added to the general conditioning received for at least a year and participating at the national-level. However, they participated in three different sports involving different physiological energy systems and having different training regimes. The primary observation of this study was that majority of the training or non-training activities showing differences in heart rate across sex, also showed differences in METS across sex. Sex differences in METs may be attributed to be a representation of the differences in intensity (in terms of heart rate) of an activity carried out by boys and girls. Further, the METs of majority of the non-training or training activities of junior athletes, irrespective of the sex or event, showed more similarity to CPA, than CEEY with RMR of Indian junior athletes exhibiting significant differences from existing compendiums.

Metabolic Equivalents or METs have been considered as an important determinant of energy cost of activities and majority of the sports nutrition practitioners and other clinicians make use of the compendium of physical activity for adults [5] or compendium of energy expenditure for youth [1] to arrive at the energy expenditure pattern of individuals and athletes. However, Ainsworth, Haskell, Whitt, Irwin, Swartz, Strath, O Brien, Bassett, Schmitz and Emplaincourt [5] has assigned a common MET value, which is not reflective of individual differences in terms of age and body composition. Previous researches have shown sex differences to be negligible for METs across different activities in children, adolescents and adults [4,5,15]. Pfeiffer, Watson, McMurray, Bassett, Butte, Crouter, Herrmann, Trost, Ainsworth and Fulton [14] found less than 2 percent

variance in MET across sex. However, Goran [27] reported a higher MET for resting energy expenditure among boys than girls. Similar to the findings in this study, where the RMR was higher among boys compared to girls, irrespective of the event. Further, sex differences in heart rate related to the differences in METs of most of the physical activities across sex. There was strong positive correlation between measured MET and Heart rate (r = 0.846; *P-value < 0.01*) and the predictability of MET from heart rate was also significant (R^2 = 0.848, SEE = 1.196; MET = -5.264 + 0.086 × Heart rate) and a similar association was also found between energy cost and heart rate (R^2 = 0.810, SEE = 1.205; Energy Cost = -4.523 + 0.076 × Heart rate). This strong association reflects a possible variation in intensity with which a specific training activity is carried out across sex. Thus, resulting in the sex differences observed for measured METs among activities in the present study and this needs to be explored further.

Byrne, *et al*. [28] reported significant differences in MET across age and body mass index, with lower age and BMI exhibiting higher RMR, compared to higher age and BMI. Other studies have reported that resting energy expenditure of children was higher than adults [14,29]. Therefore, while arriving at energy expenditure of an activity, the MET of that activity corrected using RMR (either predicted or measured) resulted in minimal difference with measured MET [28] and this correction minimizes the error while using METs [29]. However, Pfeiffer, Watson, McMurray, Bassett, Butte, Crouter, Herrmann, Trost, Ainsworth and Fulton [14] reported that one MET value across 9–15 years of age can increase chances of error up to 15–20% and suggested age-grouping as a best approach over assessing pubertal stages to assign MET. Among soccer players, a comparison was made between junior and senior boys. In the present study, most of the warm up and weight training activities showed similar METs across senior and junior soccer players. Activities which showed a significantly higher MET among junior boys, were sedentary activities like sitting & walking and lower to moderate intensity training activities like Technical warm up, wrist curl, interspersed rest and cool down stretching etc. This was in line with the findings of Pfeiffer, Watson, McMurray, Bassett, Butte, Crouter, Herrmann, Trost, Ainsworth and Fulton [14] that as age increases the MET for sedentary or light intensity activity decreases. However, contrary to the findings of Trost, Drovandi and Pfeiffer [4] that MET for sedentary or light activities remain stable across children and adolescent aged 6–16 years, while MET for sporting and fitness activities, especially walking and running tend to increase with age. In the present study, even the RMR MET of Junior boys were lower than senior boys, without correcting for body mass. This disparity might be due to the limited sample size of Junior boys and need further exploration for its relation to the improved efficiency of junior boys.

Comparison of measured METs at rest and for activities with METs in existing compendium was carried out to understand the utility of existing databases for determining energy expenditure pattern. Most of these researches were conducted on children and adolescents in free-living conditions [2,14,15,29], however, to our knowledge similar assessment has not been made among junior athletes. Pfeiffer, Watson, McMurray, Bassett, Butte, Crouter, Herrmann, Trost, Ainsworth and Fulton [14] observed that among children aged 5–19 years the MET values for sedentary or light intensity activities tend to be similar to Compendium of energy expenditure for Youth (CEEY), however, MET values tend to be higher or lower for locomotor activities and bicycle riding. In the present study, the resting MET was found to be higher compared to METs of CPA and CEEY among majority of junior athletes, except for lower MET among soccer players (Junior boys and Girls). Further, the measured MET of majority of the non-training activities (Table 3) among junior athletes tend to be similar to adult compendium (CPA) than the youth compendium (CEEY). This may be due to physical and physiological conditioning of athletes being similar to adult counterparts. Harrell, McMurray, Baggett, Pennell, Pearce and

Bangdiwala [29] carried out a study on children and adolescents aged 8–18 years and found that after correcting for resting energy expenditure, the adult compendium may also be used with minimum error among children and/or adolescents. And that after attaining puberty, CPA may be used among adolescents, without adjustment of RMR. In the present study, CEEY was found to either over or underestimate MET among junior athletes. In line with this, Brandes, Steenbock and Wirsik [15] reported that CEEY among pre-schoolers tend to substantially underestimate energy expenditure. Among training activities, warm up jogging and shuttle run exhibited similar MET as CPA. MET measured for majority of the weight training activities were higher than CPA or CEEY or both. This difference could due to the broad spectrum of weight training activities, which are listed under a single activity as “weight training” in both compendiums and also because the real time measurement of these activities was based on their regular training regime of athletes, rather than individual activity measured in isolation.

Comparing METs of activities carried out by Indian junior athletes in the present study with existing literature showed that the METs and energy cost of resting metabolic rate of junior Indian boys (n = 45) were similar to METs of 10-11-year-old children from North East England, while girls (n = 46) showed significant difference in MET with similar energy cost as 10-11-year-olds [9]. The self-paced walking MET of the total junior boys and girls in this study were significantly lower than self-paced walking of 10-11-year-old children from North East England,[9] 10-12-year-old children in youth compendium [7], 10-18-year-old from US[13] and 11-12-year-old from US [4]. Further, it was also lower than walking at 4 mph by both 8-11-year-old and 13-15-year-old from North Carolina [29]. They were only similar to 0.5 mph walking by 10-12-year-old from the youth compendium. [7] Standing MET of junior athletes in this study was significantly lower than 10-12-year-old and 13-15-year-old from the youth compendium [7]. Among training activities, jogging MET of junior athletes in both athletics and soccer events were similar to 5 mph (2.24 m/sec) jogging METs of 13-15-year-old children from North Carolina [29] and also 10-12-year-old children from US [10]. Junior athletes participating in athletics event, showed similarity across a range of METs from 8 to 8.8 for jogging at 4.5 to 5.5 mph (2.01–2.46 m/sec) of 13-15-year-old children in youth compendium [7]. Among soccer players, Joging MET of boys in the present study was comparable to running METs ranging from 7.2 to 8.1 in the youth compendium[7], while girls showed similarity to a range of 7.4 to 8.1 MET, irrespective of age category. Junior 11-year-old boys in soccer showed similarity with running MET in the range of 7.4 to 9.1 among 10-12-year-old in the youth compendium [7]. Cool down exercise METs were significantly higher among soccer players than 8–18 year-old children from US [29].

Among weight training activities, MET for push-ups of junior 11-year-old boys in soccer showed similarity to 10-12-year-old from youth compendium [7], while senior boys showed significantly higher MET. METs for activities like Bench press and Leg press among soccer players were significantly higher than youth compendium [7] and similar aged adolescents from US [29]. This higher MET for an anaerobic activity is because these activities were not carried out in isolation, but were in order of their regular protocol of starting with warm up jogging, followed by strength conditioning exercises like push-ups, crunches, jumps etc. This is also a pattern followed by athletes, and this was also a reason why the interspersed rest activities were separately measured, since they showed higher METs than regular non-training activities. Box Jump activity was compared with Jump Rope from Youth Compendium, where senior girls in soccer showed similarity in METs across both age-categories (10-12-year-old and 13-15-year-old), while junior boys showed significantly higher METs.

Although this study is limited by a smaller sample size with RMR and energy expenditure determined in a particular season and without position-specific assessment in case of soccer, it still forms a unique database for junior athletes in general and for Indian settings in particular. It could form the basis for further research on adolescent athletes and add to the database for developing an athlete specific compendium. Since, type of physical activity is most variable and important for determining energy expenditure among athletes, this will help nutritionists, researchers and other stakeholders to arrive at individualized energy needs of junior athletes using the factorial approach.

In conclusion, the energy cost and METs determined showed sex-specific differences, especially in weight training activities, this could be due to the difference in load or intensity of activities across sex. Further, a strong association was observed between METs and energy cost of activities with heart rate, indicating that any change in heart rates would reflect in changes in corresponding intensity (METs) and the energy cost. Measured METs of a majority of the non-training activities among junior athletes were similar to corresponding activity METs in the adult compendium (CPA) than children's (CEEY). The METs specifically determined for junior athletes covered a wide range of sedentary, moderate and higher intensity activities (0.7 MET to 10.8 MET) and can be incorporated into existing compendiums for estimating energy expenditure pattern of junior athletes. Further research is warranted to validate the findings pertaining to the association between heart rate and METs and also for developing an athlete specific compendium.

Declarations

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Availability of Data and Materials

Additional data collected are not provided freely to maintain a level of confidentiality of the athletes' data, however, it will be made available from the corresponding author to interested stakeholders on reasonable request.

Authors' Contributions

KSC was involved in data collection, statistical analyses, interpretation and drafting the manuscript; AS was involved in data collection and interpretation; BN has directed the statistical analysis; VRY was involved in ideating the project and providing valuable suggestion for improving the manuscripts.

Competing Interest

The authors declare no competing interest of any form.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The Ethics approval was obtained from the Institute Ethics Committee, ICMR-National Institute of Nutrition, Indian Council of Medical Research (ICMR), Ministry of Health and Family Welfare, Hyderabad, India.

Written informed consent was obtained from the parents of the study participants and verbal assent obtained from participants.

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Tables

Table 1 List of measured training and non-training activities with corresponding compendium METs

Table 1a

Activities	Activity Description	MET & (Activity Code)	
		CPA	CEEY
Non-training activities			
RMR	Resting energy cost, close to sleeping	0.9 (07030)	0.9 (100010)
Sitting	Sitting quietly and/or listening, talking	1.0 (07020)	1.4 (120140)
Standing	Standing quietly and/or talking	1.8 (134120)	1.8 (09050)
Walking	Walking quietly and/or talking	2.5 (17151)	2.9 (240051)
Training activities			
Warm up jog	Running/jogging at 2.0 to 2.2 m/sec or 5 mph	8 (12025)	7.7 (341481)
Warm up exercise	Conditioning exercise- Light effort	3.5 (02030)	3.5 (341081)
Shuttle run	Running/jogging at 2.92 m/sec or 6.7 mph	11 (12060)	9.3 (341483)
Cool down exercise	Mild stretching and exercise	2.5 (02100)	2.5 (331590)

Table 1b Weight training activities

Activities	Category	Activity Description		MET & (Activity code)	
		Weight (kg)	Repetitions (No.)	CPA	CEEY
Wrist curl	Sr. Boys	10.4 ± 4.14	14.6 ± 3.08	3 (02130)*	2.8 (331962)*
	Jr. Boys	5	10		
	Girls	11.1 ± 2.68	11.1 ± 2.09		
Bench Press	Sr. Boys	25.7± 8.52	13.9 ± 2.13	3 (02130)*	3.5 (331963)*
	Jr. Boys	13.0 ± 2.74	11.4 ± 2.19		
	Girls	11.8 ± 2.99	9.7 ± 1.33		
Crunches	Sr. Boys	-	21.8 ± 6.39	3.5 (02030)‡	-
	Jr. Boys		25 ± 3.54		
	Girls		26.4 ±3.76		
Push-ups	Sr. Boys	-	16.4 ± 1.08	3.5 (02030)‡	-
	Jr. Boys		12 ± 2.74		
Leg press	Girls	46.8 ± 10.03	16.3 ± 4.36	3 (02130)*	3.5 (331962)*
Leg curl	Sr. Boys	11.4 ± 4.97	14.6 ± 1.34		
	Jr. Boys	10.0 ± 3.54	10.6 ± 2.61		
	Girls	13.7 ± 2.81	11.3 ± 2.81		
Shoulder Press	Girls	38.2 ± 9.89	13.9 ± 4.27	-	3.5 (331963)*
Shoulder Pull	Girls	14.1 ± 2.55	11.1 ± 3.15		
Half squat	Sr. Boys	44.3 ± 10.89	15	-	-
	Jr. Boys	5.0	13.0 ± 2.74		
Box jump	Jr. Boys	-	26.0 ± 5.48	8 (02020)#	8.3 (341472)#
	Girls		33.9 ± 12.76		
Box weight	Sr. Boys	32.9 ± 5.45	15	8 (02020)#	8.3 (341472)#
Dead Lift	Girls	32.5 ± 13.29	9.0 ± 3.38	-	-

*Note: CPA=Adult compendium of Physical Activities); CEEY=Compendium of energy expenditure for Youth); Sr. Boys = Senior Boy Boys = Junior Boys; *MET of light to moderate for CPA and hard effort for CEEY. ‡MET of Conditioning exercises (Light to moderate); #1 Rope jumping activity.*

Table 2 Energy cost of Resting Metabolic Rate (RMR) and non-training activities of junior athletes

	Sex	VO_2 (ml/kg/min)	Heart Rate (bpm)	Energy Cost (kcal/min)	MET
Total group (Boys = 45; Girls = 46)					
RMR	Boys	4.2 ± 0.48[a]	64.4 ± 6.91[a]	1.0 ± 0.18[a]	1.0 ± 0.18[a]
	Girls	3.9 ± 0.54[b]	69.2 ± 7.99[b]	0.9 ± 0.12[b]	0.9 ± 0.12[b]
Sitting	Boys	4.8 ± 0.70[a]	71.9 ± 8.75[a]	1.2 ± 0.21[a]	1.1 ± 0.16[a]
	Girls	4.3 ± 0.70[b]	75.4 ± 7.83[b]	1.0 ± 0.17[b]	1.1 ± 0.13[a]
Standing	Boys	5.1 ± 0.71[a]	83.9 ± 7.61[a]	1.2 ± 0.24[a]	1.2 ± 0.19[a]
	Girls	4.6 ± 0.80[b]	85.9 ± 7.39[a]	1.1 ± 0.18[b]	1.2 ± 0.17[a]
Walking	Boys	10.0 ± 1.39[a]	86.4 ± 7.96[a]	2.4 ± 0.48[a]	2.4 ± 0.35[a]
	Girls	10.2 ± 1.82[a]	91.3 ± 7.58[b]	2.4 ± 0.42[a]	2.6 ± 0.34[b]
Athletics (Boys = 15; Girls = 15)					
RMR	Boys	4.3 ± 0.64[a]	64.8 ± 7.18[a]	1.1 ± 0.09[a]	1.1 ± 0.09[a]
	Girls	4.4 ± 0.58[a]	73.7 ± 6.72[b]	1.0 ± 0.09[b]	1.0 ± 0.09[b]
Sitting	Boys	5.2 ± 0.56[a]	71.8 ± 9.23[a]	1.3 ± 0.15[a]	1.2 ± 0.11[a]
	Girls	4.8 ± 0.62[a]	79.7 ± 6.26[b]	1.1 ± 0.15[b]	1.1 ± 0.13[a]
Standing	Boys	5.5 ± 0.58[a]	83.0 ± 7.37[a]	1.4 ± 0.17[a]	1.3 ± 0.16[a]
	Girls	5.0 ± 0.73[a]	89.1 ± 5.99[b]	1.4 ± 0.20[b]	1.1 ± 0.14[b]
Walking	Boys	10.6 ± 0.88[a]	83.0 ± 8.47[a]	2.7 ± 0.27[a]	2.5 ± 0.30[a]
	Girls	11.6 ± 1.68[b]	94.4 ± 6.52[b]	3.3 ± 0.48[a]	2.6 ± 0.35[a]
Soccer (Senior, Sr. Boys = 14; Junior, Jr. Boys= 7; Girls = 19)					
RMR	Sr. Boys	4.1 ± 0.42[a]	61.5 ± 5.90[a]	1.1 ± 0.09[a]	1.1 ± 0.09[a]
	Jr. Boys	4.1 ± 0.36[a]	66.0 ± 8.53[a,b]	0.7 ± 0.07[b]	0.7 ± 0.07[b]
	Girls	3.5 ± 0.27[b]	68.4 ± 8.37[b]	0.8 ± 0.08[c]	0.8 ± 0.08[c]
Sitting	Sr. Boys	4.4 ± 0.75[a]	69.0 ± 8.47[a]	1.1 ± 0.19[a]	1.1 ± 0.18[a]
	Jr. Boys	5.0 ± 0.70[b]	75.9 ± 9.57[a]	0.8 ± 0.11[b]	1.2 ± 0.21[b]
	Girls	3.9 ± 0.53[c]	74.7 ± 8.29[a]	0.9 ± 0.15[b]	1.1 ± 0.14[a,b]
Standing	Sr. Boys	4.7 ± 0.79[a,b]	84.0 ± 7.61[a]	1.2 ± 0.21[a]	1.2 ± 0.24[a]
	Jr. Boys	5.2 ± 0.53[a]	86.5 ± 9.62[a]	0.9 ± 0.08[b]	1.3 ± 0.19[a]
	Girls	4.4 ± 0.71[b]	85.2 ± 7.25[a]	1.0 ± 0.13[b]	1.2 ± 0.18[a]
Walking	Sr. Boys	9.6 ± 1.91[a]	88.1 ± 5.31[a]	2.5 ± 0.51[a]	2.3 ± 0.44[a]
	Jr. Boys	10.0 ± 0.91[a]	90.0 ± 9.62[a]	1.6 ± 0.16[b]	2.5 ± 0.34[b]
	Girls	9.5 ± 1.21[a]	91.1 ± 7.28[a]	2.1 ± 0.37[c]	2.7 ± 0.30[a,b]
Weightlifting (Boys = 9; Girls = 12)					
RMR	Boys	4.4 ± 0.27[a]	67.1 ± 5.86[a]	1.2 ± 0.08[a]	1.2 ± 0.08[a]
	Girls	3.9 ± 0.35[b]	65.0 ± 6.15[a]	1.0 ± 0.06[b]	1.0 ± 0.06[b]
Sitting	Boys	4.7 ± 0.52[a]	73.7 ± 7.37[a]	1.2 ± 0.05[a]	1.1 ± 0.07[a]
	Girls	4.3 ± 0.71[a]	71.4 ± 7.05[a]	1.1 ± 0.12[b]	1.1 ± 0.12[a]
Standing	Boys	5.1 ± 0.57[a]	83.5 ± 7.27[a]	1.3 ± 0.12[a]	1.2 ± 0.09[a]
	Girls	4.6 ± 0.98[a]	83.0 ± 8.25[a]	1.2 ± 0.21[b]	1.2 ± 0.20[a]
Walking	Boys	9.5 ± 1.20[a]	86.5 ± 8.33[a]	2.5 ± 0.18[a]	2.2 ± 0.21[a]
	Girls	9.5 ± 1.94[a]	87.8 ± 8.23[a]	2.4 ± 0.42[a]	2.4 ± 0.41[a]

Note: The comparison was made across athletic b
(10-16yrs; Body Mass, BM: 50.8 ± 5.74) versus G
(10-16 yrs; BM: 44.9 ± 3.85). For soccer it was Sen
(Sr.) boys (11-16yrs; BM: 52.6 ± 6.88), Junior (Jr.) b
(10 yrs; BM: 32.9 ± 2.96) and Girls (10-16 yrs; BM: 4
± 6.58). For Weightlifting, it was boys (11-17yrs; B
53.4 ± 5.65 versus Girls (11-17 yrs; BM: 51.7 ± 6.69)

Table 3 Energy Cost of Training Activities Specific to Athletes and Football Players

	Sex	VO_2 (ml/kg/min)	Heart Rate (bpm)	Energy Cost (kcal/min)	MET
Athletics: Warm up activities					
Warm up Jogging	Boys	35.1 ± 3.64[a]	149.9 ± 7.55[a]	8.9 ± 1.20[a]	8.2 ± 1.11[a]
	Girls	36.7 ± 4.41[a]	159.9 ± 10.00[b]	10.4 ± 1.25[a]	8.3 ± 1.29[a]
Warm up exercise	Boys	13.8 ± 1.77[a]	111.1 ± 7.43[a]	3.5 ± 0.40[a]	3.2 ± 0.55[a]
	Girls	18.4 ± 4.95[b]	125.9 ± 9.65[b]	4.1 ± 1.16[b]	4.3 ± 1.34[b]
Striding	Boys	28.8 ± 3.65[a]	140.0 ± 10.62[a]	7.3 ± 1.22[a]	6.7 ± 1.10[a]
	Girls	28.8 ± 4.60[a]	144.7 ± 8.26[a]	6.5 ± 1.22[a]	6.7 ± 1.61[a]
Football: Warm up activities					
Warm up jogging	Sr. Boys	31.4 ± 4.42[a]	146.1 ± 7.70[a]	8.0 ± 1.61[a]	7.8 ± 1.14[a]
	Jr. Boys	35.7 ± 5.41[b]	144.1 ± 9.38[a]	5.9 ± 0.80[b]	8.7 ± 1.16[a]
	Girls	27.1 ± 3.77[c]	140.8 ± 7.49[a]	6.0 ± 0.71[b]	7.7 ± 0.93[a]
Warm up exercise	Sr. Boys	19.0 ± 3.14[a]	115.4 ± 9.97[a]	4.9 ± 0.90[a]	4.7 ± 0.81[a]
	Jr. Boys	19.3 ± 2.81[a]	121.3 ± 7.13[a]	3.2 ± 0.38[b]	4.7 ± 0.71[a]
	Girls	16.6 ± 1.93[b]	116.4 ± 4.12[a]	3.7 ± 0.53[b]	4.7 ± 0.56[a]
Shuttle run	Sr. Boys	37.2 ± 6.62[a]	154.9 ± 6.62[a]	9.7 ± 2.07[a]	9.2 ± 2.02[a,b]
	Jr. Boys	44.2 ± 4.94[b]	152.1 ± 5.61[a]	7.3 ± 1.10[b]	10.8 ± 1.19[b]
	Girls	31.1 ± 4.41[c]	149.0 ± 13.08[a]	7.0 ± 1.12[b]	8.9 ± 1.25[a]
Technical warm up	Sr. Boys	26.7 ± 5.34[a]	143.5 ± 12.08[a]	7.1 ± 1.79[a,b]	6.7 ± 1.48[a]
	Jr. Boys	34.7 ± 2.32[b]	139.0 ± 6.92[a]	5.8 ± 0.76[a]	8.5 ± 0.67[b]
	Girls	34.8 ± 4.93[b]	156.4 ± 8.48[b]	7.8 ± 1.10[b]	9.9 ± 1.32[c]
Football: Main training activities					
Weight Training	Sr. Boys	28.5 ± 5.67[a]	126.0 ± 11.20[a]	7.5 ± 1.66[a]	7.1 ± 1.29[a]
	Jr. Boys	35.5 ± 4.26[b]	120.5 ± 8.09[a]	5.8 ± 0.48[b]	8.7 ± 1.07[b]
	Girls	25.2 ± 5.66[a]	132.9 ± 8.10[b]	5.5 ± 0.81[b]	7.1 ± 1.46[a]
Step conditioning	Sr. Boys	20.2 ± 3.75[a]	145.1 ± 13.33[a]	5.2 ± 0.89[a]	5.0 ± 0.86[a]
	Jr. Boys	21.1 ± 2.40[a]	143.5 ± 8.58[a]	3.5 ± 0.48[b]	5.2 ± 0.78[a]
	Girls	17.6 ± 2.00[b]	150.1 ± 11.5[a]	3.9 ± 0.44[b]	5.0 ± 0.57[a]
Football: Interspersed rest and Cool down					
Interspersed walk	Sr. Boys	15.9 ± 2.24[a]	112.9 ± 11.31[a]	4.1 ± 0.38[a]	3.9 ± 0.39[a]
	Jr. Boys	24.6 ± 2.45[b]	128.0 ± 18.05[a]	4.1 ± 0.34[a,b]	6.0 ± 0.57[b]
	Girls	16.6 ± 2.28[a]	125.4 ± 28.69[a]	3.7 ± 0.34[b]	4.7 ± 0.57[c]
Interspersed standing	Sr. Boys	12.8 ± 1.49[a]	104.4 ± 11.21[a]	3.3 ± 0.36[a]	3.1 ± 0.37[a]
	Jr. Boys	18.0 ± 2.87[b]	116.6 ± 12.43[a,b]	3.0 ± 0.65[a]	4.4 ± 0.63[b]
	Girls	14.0 ± 2.28[a]	123.7 ± 13.43[b]	3.1 ± 0.35[a]	4.0 ± 0.61[b]
Interspersed sitting	Sr. Boys	10.2 ± 0.88[a]	100.7 ± 11.06[a]	2.7 ± 0.37[a]	2.5 ± 0.26[a]
	Jr. Boys	13.6 ± 3.32[b]	108.1 ± 14.20[a,b]	2.3 ± 0.63[a]	3.3 ± 0.66[b]
	Girls	11.2 ± 1.85[a]	115.9 ± 13.70[b]	2.5 ± 0.39[a]	3.2 ± 0.53[b]
Cool down stretching exercises	Sr. Boys	14.6 ± 2.12[a]	112.7 ± 10.79[a]	3.8 ± 0.45[a]	3.6 ± 0.43[a]
	Jr. Boys	19.0 ± 4.98[b]	115.3 ± 19.46[a]	3.1 ± 0.69[b]	4.7 ± 1.41[b]
	Girls	12.9 ± 2.62[a]	120.4 ± 14.27[a]	2.9 ± 0.51[b]	3.7 ± 0.73[a]

Note: The sample size for each of t training activity is depicted in Figure 2 a the Interspersed rest and cool do activities had similar sample as warm activities. The comparison was ma across athletic boys (10-16yrs; Body Ma BM: 50.8 ± 5.74) versus Girls (10-16 y BM: 44.9 ± 3.85). For soccer it was Sen (Sr.) boys (11-16yrs; BM: 52.6 ± 6.8 Junior (Jr.) boys (10 yrs; BM: 32.9 ± 2. and Girls (10-16 yrs; BM: 45.1 ± 6.58).

Training Activities	Category	VO_2 (ml/kg/min)	Heart Rate (beats/min)	Energy Cost (kcal/min)	MET
Football: Weight training activities					
Wrist curl	Sr. Boys	11.5 ± 2.07[a]	105.5 ± 9.48[a]	3.0 ± 0.70[a]	2.9 ± 0.63[a]
	Jr. Boys	14.3 ± 3.36[b]	107.9 ± 14.79[a]	2.4 ± 0.64[b]	3.5 ± 0.95[b]
	Girls	9.0 ± 1.86[c]	108.8 ± 11.82[a]	2.0 ± 0.23[b]	2.6 ± 0.46[a]
Bench Press	Sr. Boys	18.6 ± 4.75[a]	117.5 ± 20.11[a]	4.8 ± 1.06[a]	4.5 ± 0.99[a]
	Jr. Boys	16.8 ± 3.92[a]	114.9 ± 12.55[a]	2.8 ± 0.55[b]	4.1 ± 1.08[a,b]
	Girls	12.0 ± 2.04[b]	113.7 ± 9.61[a]	2.7 ± 0.35[b]	3.4 ± 0.56[b]
Crunches	Sr. Boys	16.7 ± 2.81[a]	117.5 ± 13.05[a,b]	4.2 ± 0.91[a]	4.1 ± 0.76[a]
	Jr. Boys	17.6 ± 2.31[a]	110.5 ± 7.84[b]	2.9 ± 0.39[b]	4.3 ± 0.50[a]
	Girls	15.9 ± 3.07[a]	124.5 ± 12.94[a]	3.3 ± 0.96[b]	4.3 ± 1.29[a]
Push ups	Sr. Boys	18.6 ± 4.79[a]	124.9 ± 10.92[a]	4.8 ± 1.19[a]	4.6 ± 1.02[a]
	Jr. Boys	18.3 ± 1.98[a]	115.1 ± 8.35[a]	3.0 ± 0.56[b]	4.5 ± 0.57[a]
Leg press	Girls	17.5 ± 2.15	132.8 ± 7.48	3.9 ± 0.55	5.0 ± 0.64
Leg curl	Sr. Boys	16.7 ± 3.53[a]	114.4 ± 13.28[a]	4.4 ± 0.79[a]	4.1 ± 0.87[a]
	Jr. Boys	20.0 ± 2.45[a]	116.4 ± 9.75[a]	3.3 ± 0.65[b]	4.9 ± 0.55a[a,b]
	Girls	17.4 ± 3.04[a]	133.4 ± 12.63[b]	3.9 ± 0.68[b]	5.0 ± 0.84[b]
Shoulder Press	Girls	18.2 ± 2.64	135.9 ± 10.18	4.1 ± 0.63	5.2 ± 0.69
Shoulder Pull	Girls	18.4 ± 2.65	138.8 ± 10.85	4.1 ± 0.64	5.2 ± 0.75
Half squat	Sr. Boys	22.8 ± 6.49[a]	134.7± 16.01[a]	5.8 ± 1.43[a]	5.6 ± 1.36[a]
	Jr. Boys	22.8 ± 3.05[a]	129.2 ± 8.43[a]	3.8 ± 0.60[b]	5.6 ± 0.74[a]
Box jump	Jr. Boys	35.5 ± 3.15[a]	144.2 ± 15.29[a]	5.8 ± 0.20[a]	8.7 ± 1.12[a]
	Girls	26.6 ± 3.49[b]	159.7 ± 11.20[b]	5.9 ± 0.75[a]	7.6 ± 1.06[b]
Box jump with weight	Sr. Boys	29.1 ± 6.11	147.6 ± 14.49	7.5 ± 1.57	7.2 ± 1.55
Dead lift	Girls	18.9 ± 1.57	137.1 ± 9.94	3.7 ± 1.42	4.7 ± 1.76

Table 4 Energy Cost of Weight Training Activities in Junior Football Players

Note: The sample size for the weight train activity is depicted in Figure 2. The comparis was made across athletic boys (10-16yrs; Body Mass, BM: 50.8 ± 5.74) versus Girls (10-16 yrs; BM: 44.9 ± 3.85). For soccer, it was Senior (Sr.) boys (11-16y BM: 52.6 ± 6.88), Junior (Jr.) boys (10 yrs; BM: 32.9 ± 2.96) and Girls (10-16 yrs; BM: 45.1 ± 6.58).

Figures

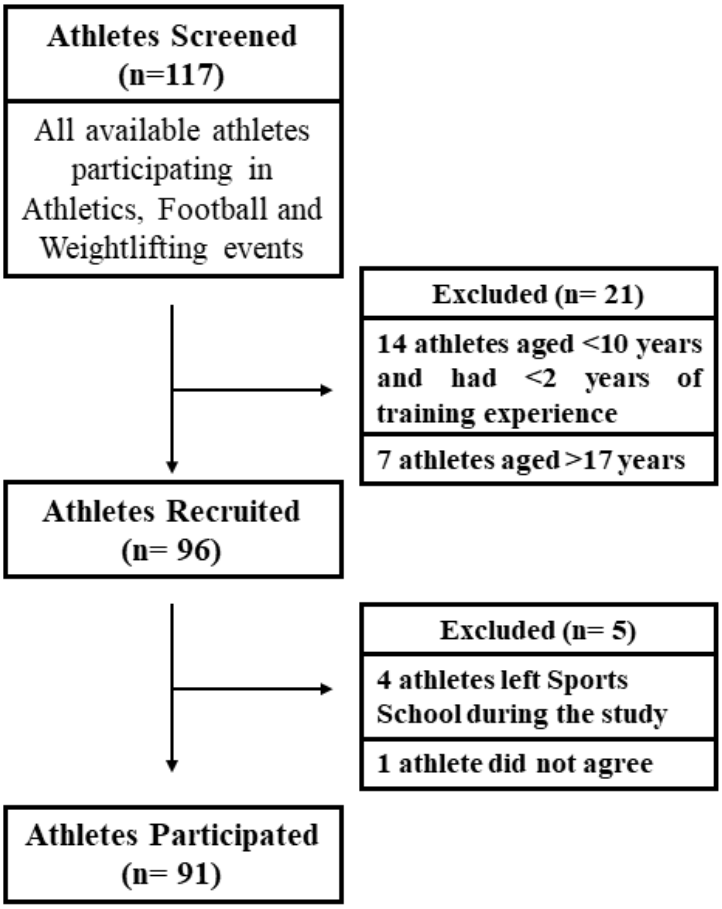


Figure 1

Participant Screening and Pathway

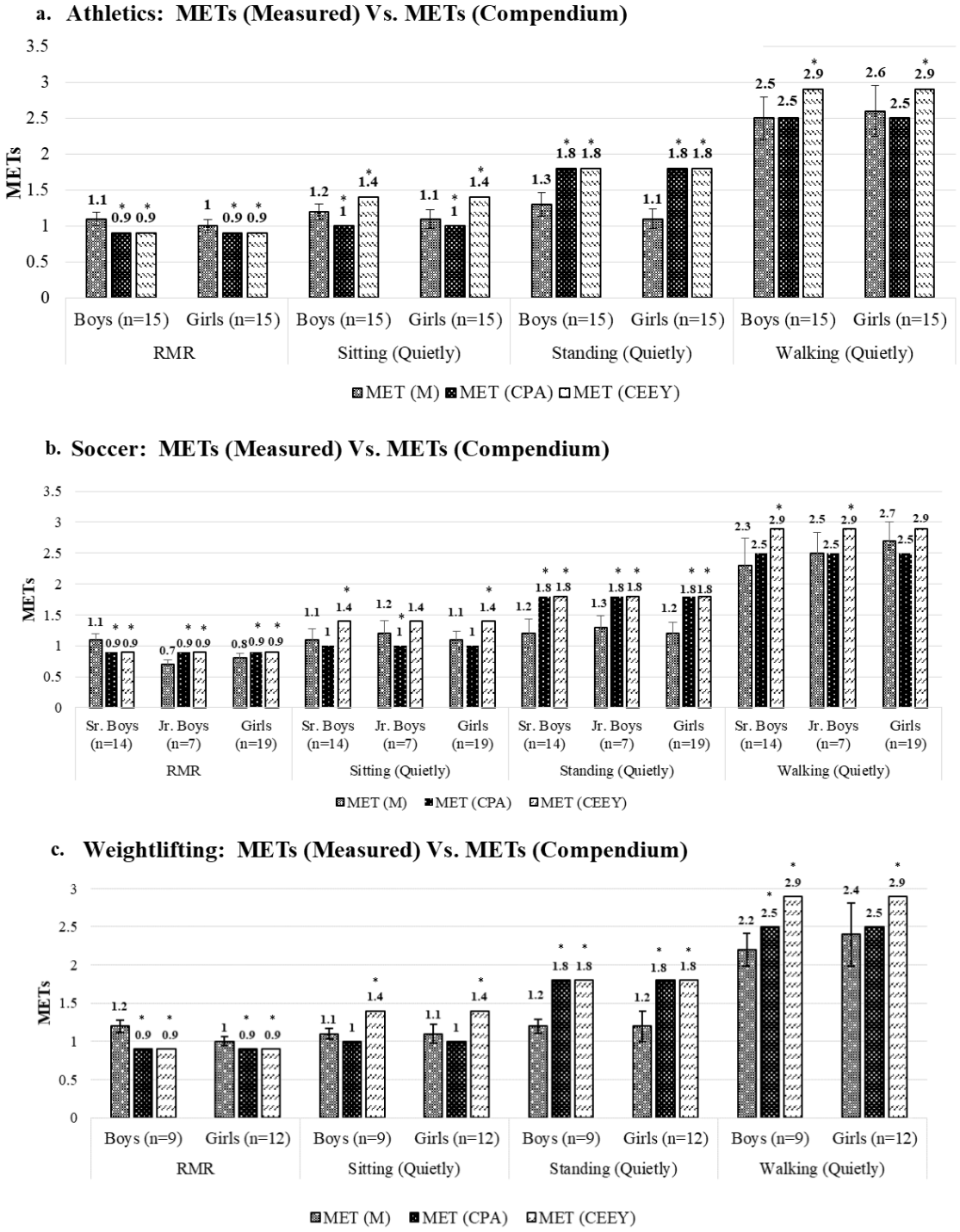
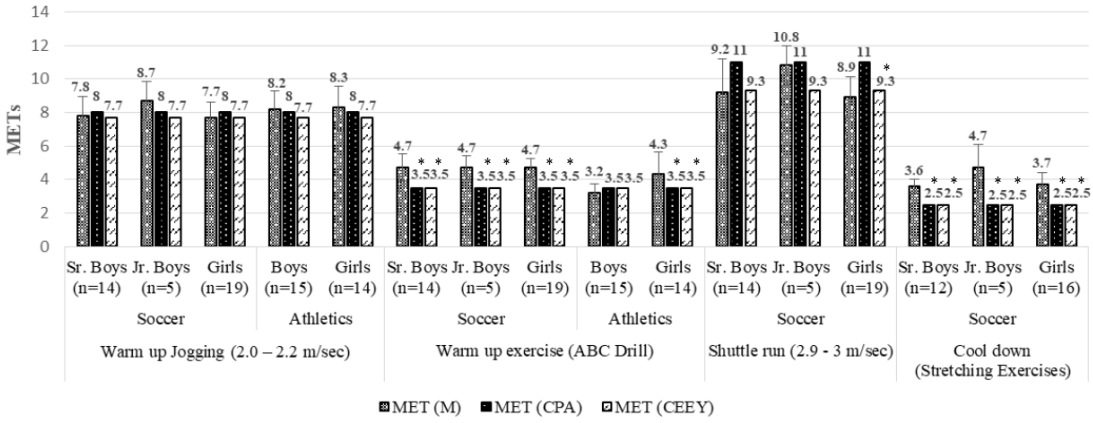


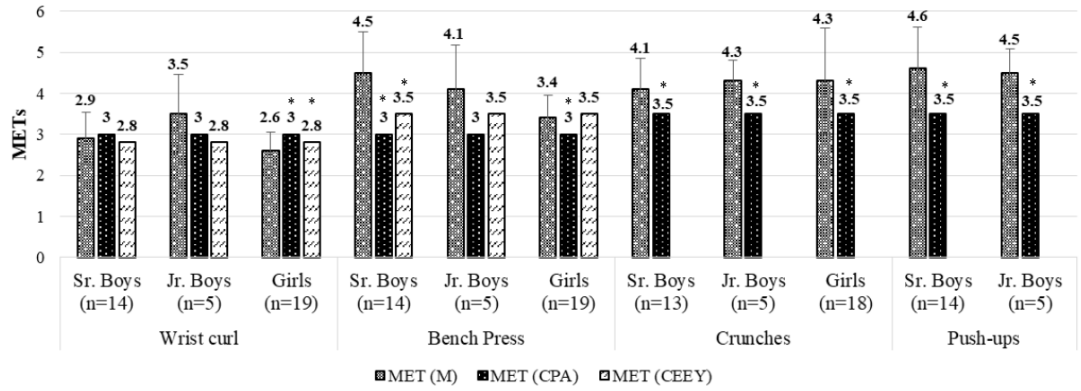
Figure 2

Comparison of Measured METs of Non-Training Activities with METs of Compendium Note: METs = Metabolic Equivalents; M = Measured; CPA = Compendium of Physical Activity by Ainsworth, Haskell, Whitt, Irwin, Swartz, Strath, O Brien, Bassett, Schmitz and Emplaincourt [5]; CEEY = Compendium of energy expenditure for youth by Ridley, Ainsworth and Olds [1]. *Significant difference between CPA and/or CEEY versus measured METs.

a. **METs (Measured) Vs. METs (Compendium)**



b. **Soccer: METs (Measured) Vs. METs (Compendium)**



c. **Soccer: METs (Measured) Vs. METs (Compendium)**

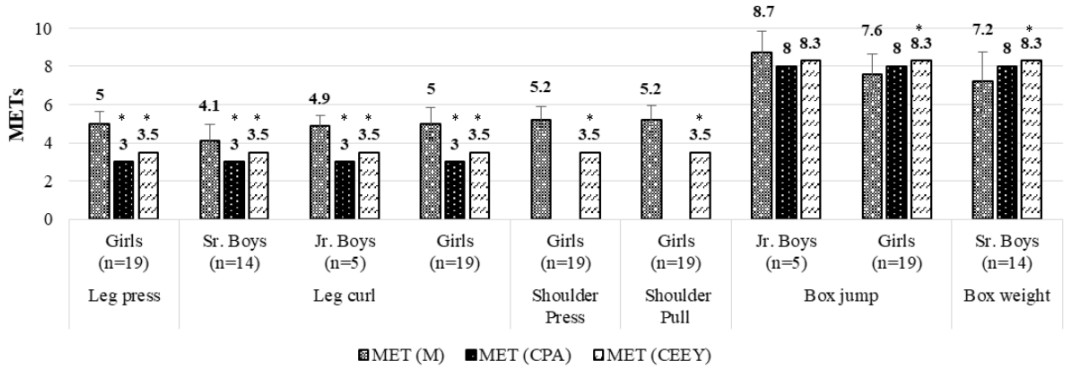


Figure 3

Comparison of Measured METs of Training Activities with METs of Compendium Note: METs = Metabolic Equivalents; M = Measured; CPA = Compendium of Physical Activity by Ainsworth, Haskell, Whitt, Irwin, Swartz, Strath, O Brien, Bassett, Schmitz and Emplaincourt [5]; CEEY = Compendium of energy expenditure for youth by Ridley, Ainsworth and Olds [1]. *Significant difference between CPA and/or CEEY versus measured METs.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- StrobeChecklist02042020.doc
- StrobeChecklist02042020.doc