Monitoring Energy Expenditure Indexes by Actigraph Sensor in Physical Activities

Bo Zhou
Physical Culture College, Hunan Normal University
Changsha, Hunan
410012, China

Chao Zhou
P.E. Department, Hunan University of Arts and Science
Changde, Hunan
415000, China
zb05656@163.com

ABSTRACT: *The physical activities are helpful for the health of teenagers as it can strengthen constitution and bone health and lower risks of cardiovascular disease and metabolic disease. Actigraph sensor can more accurately evaluate energy expenditure of teenagers during physical activities. This study observes and researches energy expenditure indexes of human body in physical activities combining Actigraph sensor, in order to provide a basis for studying the relationship between physical activities and health.*

Keywords: Actigraph sensor, Health monitor sensors, Energy expenditure

Received: 18 August 2016, Revised 23 September 2016, Accepted 4 October 2016

1. Introduction

In physical activities, skeletal muscle contraction consumes people's energy. *Kj* can be taken as the measurement unit for the energy expenditure in physical activities [1~3]. Many studies reveal that, physical fitness and health level of children and teenagers can be significantly improved through regular physical activities [4, 5]. Observing and studying physical activities of teenagers and measuring energy expenditure level are of great importance for scientifically guiding physical activities and promoting physical fitness and health level of teenagers. Aceleration sensor is widely used in studying physical activities of children in recent ten years as the small and convenient device can effectively reduce the subjectivity and accurately provide information about energy expenditure, frequency, strength and duration time of physical activities [6, 7]. Related data demonstrates that, teenagers who often take part in physical activities have obviously higher health level than those who seldom participate in physical activities. It is believed that, physical activities of teenagers and their healthy growth are in a close correlation. Sensor device is able to transform amount of information to be measured into a kind of signal device convenient for transmission and measurement in the process of using according to chemical quantity, physical quantity and other rules of metrical information, which not only controls and detects automatically, but also realizes the transmission, storage and control of information to be measured. To date, good application effects have been achieved in each field based on different measurements of sensor. Actigraph sensor, a tiny and convenient tool for measuring physical activities, can accurately evaluate the energy consumed in physical activities [8].

For instance, since 2003, America has used Actigraph acceleration sensor into national nutrition and health survey [9]; England has also applied it in studies of physical activities of children, as stated in Avon parents and children long-term investigation [10]. But in China, few studies concern the measurement of physical activities by Actigraph acceleration sensor. Thus this study uses Actigraph GT3X sensor to measure the energy expenditure level of teenagers in physical activities, in order to explore the physical activities of teenagers and the application of the sensor in physical activities of teenagers.

2. Actigraph Sensor

2.1 Principle of Actigraph Sensor

Actigraph sensor was developed by America. De Vries points out that, a series of Actigraph sensors (GT1M, GT3X, GT3X+, Actitrainer) have been widely used in research field now. Actigraph sensor can synchronously monitor vertical axis AC (ACz)· sagittal axis AC (ACy) and coronal axis AC (ACx) and convert them into comprehensive vector magnitude (VM) and horizontal AC (ACh). The calculation methods for VM and ACh are:

$VM = (AC^2_x + AC^2_y + AC^2_z)1/2$ and $VM = (AC^2_x + AC^2_y + AC^2_z)1/2$. This study tests energy expenditure of teenagers in physical activities taking GT3X in Actigraph triaxial acceleration sensor as an example [11].

GT3X triaxial acceleration sensor is applied the most frequently, with an internal storage of 16 MH, battery life of 20 days, sampling frequency of 30 Hz and sampling scope of 0.05 ~ 2.5 G/s. During experiment, GT3X triaxial acceleration sensor is placed on the right medulla of teenagers where is close to the level of navel. Actilife 6.0 software is used for fulfilling proof-reading, setting and data processing, and indirect calorimetry is adopted for monitoring energy expenditure of teenagers in physical activities and Cosmed k4b2 gas metabolism method is for analysis. Teenagers should immediately press the start button on Cosmed k4b2 within specific time to ensure data to be consistent with GT3X and the accuracy and precision of the experiment [12].

2.2 Energy Consumption Calculation Equation Based on Actigraph Sensor

Authors	Calculation equation (METs=)	R2	SEE
Freedson et al.	1.439008+0.000795×cpm	0.82	1.12
Hendelman et al.	1.602+0.000638×cpm	0.59	0.87
Hendelman et al.	2.922+0.000409×cpm	0.35	0.96
Swartz et al.	2.606+0.0006883×cpm	0.32	1.16
Nichols et al.	1.384+0.0008157×cpm	0.89	1.38
Leenders et al.	2.24+0.0006×cpm	0.74	0.53
Yngve et al.	0.75+0.0008198×cpm	0.86	1.1
Yngve et al.	1.136+0.0008294×cpm	0.85	1.14

Table 1. Linear regression equation based on Actigraph

Acceleration sensor directly records counts data, and a regression equation between counts and energy consumption has to be established to obtain energy expenditure information of human body during exercise. At present, academic circle mainly sets up two kinds of energy calculation equations based on Actigraph, including linear equation and section equation [13].

There are 8 commonly used linear equations built on the Actigraph acceleration sensor measurement results (table 1), which play an very important role in studying physical activities, especially, Freedson and other derivation regression equations have been accepted by Actilife client software derived from Actigraph [14]. Crouter et al found that no equation could accurately predict energy consumption of all physical activities when verifying energy calculation equation of Actigraph. Sasaki et al [15] built predictive model using multiple regression containing elements of speed and counts with GT3X and performed paired samples T test with actual energy expenditure in control group, which discovered no sign of significant difference. Despite this fact, an equation is able to present an excellent validity only when calculating energy in corresponding type and intensity of physical activity, because equation is usually established on a specific exercise type and intensity. Hence, a scholar [16] comes up with a method of building section equation to improve this situation.

3. Research Objects and Methods

3.1 Research Objects

Healthy teenagers in age of 20 years are selected as research objects and divided into two groups. One group includes 30 girls and 30 boys (test group) and the other group composes of 30 girls and 30 boys (validation group). Totally 120 people take part in the test. Teenagers in two groups have no obvious difference in anthropometric characteristics ($P>0.05$), as shown in table 2. The participants are required not to do vigorous physical activities the day before joining in the experimental research. All experimental activities are carried out one hour after meal.

	Test group		**Validation group**	
	Male (n=30)	**Female (n=30)**	**Male (n=30)**	**Female (n=30)**
Age (year)	21.9±1.5	21.5±1.0	22.5±2.3	21.5±1.4
Height (cm)	172.8±6.1	163.2±5.7	172.5±7.5	162.6±5.5
Weight (kg)	66.4±8.2	54.8±7.7	66.2±11.3	55.2±6.6
Body fat rate (%)	18.9±2.8	24.5±4.2	18.2±2.6	24.5±4.6
BMI (kg/m2)	21.4±2.3	20.7±2.3	22.8±2.4	20.7±1.5

Table 2. Anthropometric characteristics of participants

3.2 Experimental Scheme

The following preparations need to be done first, in order to obtain the best experimental purpose.

A. Experimental time: 8 a.m. to 12:30 p.m. and 1:00 p.m.to 5:30 p.m.

B. Test place: gymnasium in campus

C. Temperature: 18 °C ~ 25 °C, temperature change is controlled between 50% and 80%.

D. Dressing of the participants: sportswear.

After entering the experimental field, height, weight and body fat rate of teenagers are first measured. Next, they are required to wear GT3X triaxial acceleration sensor and get familiar with the use procedures of k4b2. In this experiment, 120 teenagers should fulfill 2 categories containing 7 sports activities in total, walking/running physical activities including slow walking (4 km/h), jogging (8 km/h) and fast walking (6 km/h) and non-walking/running physical activities including sit still, clearing up the desk (standing posture), reading (sitting posture) and sweeping the floor.

This experiment lasts for 4 hours for better verification. Before the experiment, these teenagers should first fill out a piece of weekly physical activities report. We can know the time consumed by physical activities in one week based on the report and as Cosmed k4b2 gas metabolism energy analyzer used in this experiment can only work for 2 hours once and the operation will take one to two minutes. Data during this period are excluded. In the 4-hour experiment, the participants spend 230 to 240 minutes to consume energy.

3.3 Data Statistics

Data is processed by SPSS 15.0 statistical software. Data produced by GT3X triaxial acceleration sensor and Cosmed k4b2 gas metabolism energy analyzer are analyzed using Pearson associated analysis method. $P>0.05$ is defined as significant level and $P<0.01$ is as highly significant level.

4. Results

	Activity mode	**ACz**	**ACh**	**VM**
Kcal/min	Walking /running	0.85	0.34	0.85
	Non walking/running	0.73	0.75	0.77
	Walking/running + non walking/running	0.93	0.73	0.94
METs	Walking/running	0.91	0.44	0.91
	Non walking/running	0.83	0.85	0.85
	Walking/running + non walking/running	0.96	0.82	0.96

Table 3. Correlation between energy expenditure of teenagers in physical activities and AC

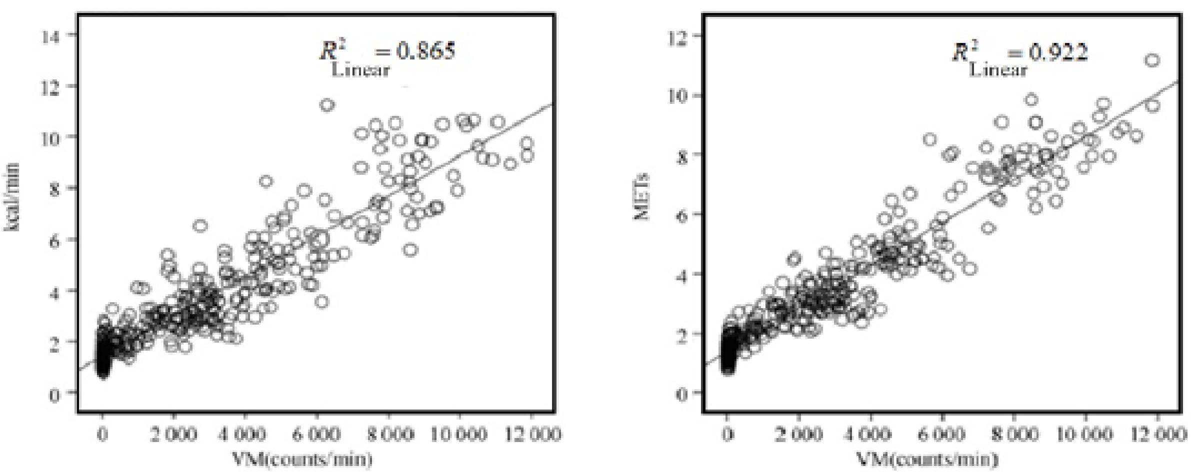

Figure 1. Scatter diagram for the correlation between VM and energy expenditure

Correlation of energy expenditure of teenagers in physical activities and AC is concluded from the above research (table 3). If $P<0.01$, the correlation between AC and energy expenditure in physical activities of teenagers demonstrates a highly significant level. However, the correlation between ACh and energy expenditure in physical activities is closely related to specific activities; in walking/running activities, VM and ACz are both in a close correlation with energy expenditure in physical activities, but the correlation between ACh and energy expenditure is not obvious; the change of correlation between VM and energy expenditure is the smallest. Thus we can take VM as the optimal independent variable for calculating energy expenditure. In view of comprehensive data of the seven physical activities in the experiment, VM is in a highly positive correlation with energy expenditure ($P<0.01$) (Figure 1).

5. Analysis and Discussion

Actigraph triaxial acceleration sensor, the most frequently used monitoring instrument, has been applied in many physical activities and obtained satisfactory effect. It can effectively supervise energy expenditure in physical activities. Physical activities are divided into two categories in this study based on the previous studies, i.e., non-walking/running and walking/running. This study establishes an energy expenditure equation for Actigraph triaxial acceleration sensor taking VM as the independent variable to more accurately monitor energy expenditure in physical activities, based on the principle of lowering error to the largest extent [17]. Acceleration sensor plays a vital function in physical activity measurement for its own characteristics. Actigraph is the most widely used acceleration sensor now. Reviewing the reliability and validity studies [18], we find that, Actigraph applied in monitoring physical activities demonstrates sound reliability and validity level in the foreign studies, especially when compared with other types of acceleration sensors. There is a high consistency between instruments of different generations and between instruments of same generation and different versions in data recording precision. Meanwhile, we should notice that, Actigraph energy calculation model is usually established based on laboratory studies. Thus, precisions of Actigraph in measuring and evaluating individual physical activities need to be further proved [19].

Monitoring physical activities of Chinese people by acceleration sensors, such as Actigraph, has been seldom reported. In view of the advantages of acceleration sensors in measuring energy expenditure, daily health management method and requirements on instruments, we should pay more attention to the studies about measuring physical activities by acceleration sensors represented by Actigraph, create physical activity evaluation method suitable for the characteristics of Chinese people combining with the constitution and motion form of Chinese and develop physical activity monitoring instruments suitable for Chinese.

6. Conclusion

Using Actigraph GT3X triaxial acceleration sensor, this experiment analyzes and evaluates the energy expenditure of teenagers in physical activities with VM as the optimal independent variable for calculating energy expenditure, providing a scheme for accurately monitoring energy expenditure of teenagers in physical activities. Besides, in future studies, age scope and research field are suggested to be expanded and more physical activities are advised to be added into the study, in order to figure out an energy expenditure monitoring scheme suitable for all groups and fields, ensure people’s health comprehensively and improve national physical quality.

References

[1] Kohrt, W. M., Bloomfield, S. A., Little, K. D. (2004). Physical Activity and Bone Health. *Medicine & Science in Sports & Exercise*, 36(11) 1985-1996.

[2] Hayman, L. L., Himmelfarb, C. D. (2014). Physical Activity and Cardiovascular Health. *Journal of Cardiovascular Nursing*, 29(3) 203-204.

[3] Joseph, R. P. (2014). Internet-Based Physical Activity Interventions. *American Journal of Lifestyle Medicine*, 8(1) 42-68.

[4] Biddle, S. J., Gorely, T., Stensel, D. J. (2004). Health-enhancing Physical Activity and Sedentary Behavior in Children and Adolescents. *Journal of Sports Sciences*, 22(8) 679-701.

[5] Biddle, S. J., Asare, M. (2011). Physical Activity and Mental Health in Children and Adolescents: a Review of Reviews. *Br J Sports Med*, 45(11) 886-895.

[6] Magnus, D., Andersen, B.Lars. (2011). Accelerometer-measured Daily Physical Activity Related to Aerobic Fitness in Children and Adolescents. *Journal of Sports Sciences*, 29(9) 887-895.

[7] Janssen, X., Basterfield, L., Parkinson, K. N. (2014). Sitting Time and Changes in Sitting Time in Children and Adolescents: Impact of Accelerometer Data Reduction Decisions. *Science & Sports*, 29 S44.

[8] Soric, M., Turkalj, M., Kucic, D. (2013). Validation of a Multi-sensor Activity Monitor for Assessing Sleep in Children and Adolescents. *Sleep Medicine*, 14(2) 201–205.

[9] Mark, A. E., Janssen, I. (2008). Dose-Response Relation between Physical Activity and Blood Pressure in Youth. *Medicine & Science in Sports & Exercise Official Journal of the American College of Sports Medicine*, 40(6) 1007-1012.

[10] Golding, M. P. R. J. (2001). ALSPAC—the Avon Longitudinal Study of Parents and Children. I. Study Methodology.

Paediatric & Perinatal Epidemiology, 15 (1) 74-87.

[11] Trost, S. G., Loprinzi, P. D., Moore, R. (2011). Comparison of Accelerometer Cut Points for Predicting Activity Intensity in Youth. *Med Sci Sports Exerc*, 43 (7) 1360-1368.

[12] Howe, C. A., Staudenmayer, J. W., Freedson, P. S. (2009). Accelerometer Prediction of Energy Expenditure: Vector Magnitude versus Vertical Axis. *Med Sci Sports Exerc*, 41 (12) 2199-2206.

[13] Reilly, J. J., Kelly, L. A., Montgomery, C. (2011). Validation of Actigraph Accelerometer Estimates of Total Energy Expenditure in Young Children. *International Journal of Pediatric Obesity*, 1 (3) 161-167.

[14] Yao, M., Kim, H.C. (2012). A Review of Accelerometer-Based Physical Activity Measurement. *Lecture Notes in Electrical Engineering*, 223-237.

[15] John, D., Sasaki, J., Hickey, A. (2014). ActiGraph Activity Monitors: “The Firmware Effect. *Medicine & Science in Sports & Exercise*, 46 (4) 834-839.

[16] Croutcr, S. E., Churilla, J. R., Bassctt Jr, D. R. (2006). Estimating Energy Expenditure Using Accelerometers. *European Journal of Applied Physiology* (6) 601-612.

[17] Zhu, Z., Chen, P., Zhuang, J. (2013). Predicting Chinese Children and Youth’s Energy Expenditure Using ActiGraph Accelerometers: a Calibration and Cross-validation Study. *Research Quarterly for Exercise & Sport*, 84 suppl 2: S56-63.

[18] O’Neil, M. E., Fragala-Pinkham, M. A., Forman, J. L. (2014). Measuring Reliability and Validity of the ActiGraph GT3X Accelerometer for Children with Cerebral Palsy: a Feasibility Study. *Journal of Pediatric Rehabilitation Medicine*, 7 (3) 233-240.

[19] Hänggi, J. M., Phillips, L. R., Rowlands, A. V. (2013). Validation of the GT3X ActiGraph in Children and Comparison with the GT1M ActiGraph. *Journal of Science & Medicine in Sport*, 16 (1) 40-44.