ISSN : 0974 - 7435 Volume 10 Issue 9

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(9), 2014 [3973-3978]

A study on determination of best critical value of steps/min in diagnosis exercise intensity for Chinese adolescents by receiver operating characteristic (ROC) curve analysis

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ABSTRACT

Purpose: This study aims at evaluating the diagnostic value of steps/min in differentiating exercise intensity through Receiver Operating Characteristic (ROC) curve so as to determine the best cutoff point of steps/min for Light Physical Activity (LPA), Moderate Physical Activity (MPA) and vigorous physical activity (VPA) for Chinese children. **Method:** With the synchronous monitor of the portable gas metabolic analyzer (Cosmed K4b2) and three-axis accelerometer (ActiGraph GT3X), 60 subjects of 11-14 years old middle school students (being evenly composed of males and females) would be tested with resting and 3~8km/h walking/running exercises. The experimental data were used to draw a ROC curve. **Result:** The result showed that there was no gender difference ($P>0.05$) between males and females on steps/min and exercise intensity when they conducted the same activity; the corresponding AUC of 3METs and 6METs was 0.906($P<0.05$) and 0.895($P<0.05$) respectively, which manifested that steps/min had great value to diagnose the exercise intensity. The best critical point of steps/min for 3METs and 6METs determined by the maximum Youden value was 121 steps/min and144 steps/min respectively with high sensitivity (0.744~0.944) and low 1-specificity (0.035~0.160). Steps/min was effective to differentiate the best critical point of exercise intensity, and the consistency examination result was also good. **Conclusion:** It can be concluded from this study that steps/min is effective to diagnose the exercise intensity and the best critical value of steps/min for the adolescents to do MPA is 121 steps/min to 144 steps/min and ≥144 steps/min for VPA.

KEYWORDS

Exercise intensity; ROC curve; Steps/min; Best critical point.

INTRODUCTION

The theory of dose-effect was first applied in pharmacology, referring to the corresponding relation between the dose and the effect caused, which was very important to make clinical treatment decisions and in experimental pharmacology. In 1994, Professor Haskell, an American sports medicine expert applied this theory to the study of physical exercise and he confirmed that the dose-effect relation also existed between physical activities and human health, namely, the production of certain effects depended on the dose used, and the dose here included the type, intensity, time and frequency of the physical activity.

At present, all the adolescents around the world are facing two common problems. One is over nourishment and the other is the lack of exercise. Physical decline is the direct impact caused by the lack of exercise, which is more obvious for the children; however, often participating in appropriate physical activities can promote their growth and health[1]. Moreover the physical activity pattern formed in the childhood can be kept to the adulthood[2], which can help them to reduce the risk of suffering from cardiovascular disease, diabetes and other diseases when they grow up[3]. Therefore, many countries in the world had issued some guidelines to guide the children and adolescents with their physical activities. However, these guidelines just gave directive guidance, and it was very hard for the subjects to judge the intensity of their activities. Walking/running is a basic human activity and has also been recognized as one of the best sports since it is less affected by the environmental conditions. With the help of the gas metabolic analyzer and motion accelerometer, this study would recommend the best steps/min for the adolescents on the base of a ROC curve as well as set the dose information like exercise intensity and so on for the major exercise type of walking/running. This study would provide a potential standard for efficiently guiding the Chinese adolescents' daily fitness and accurately evaluating the intensity level of their physical activities, and it would also be an alternative physical activity model recommended to the Chinese adolescents.

EXPERIMENTAL SECTION

60 subjects between the age of 11 and 14 years old voluntarily participated in this study (being evenly composed of 30 males and 30 females and the average age was 12.99 ± 0.93 years old). All subjects were healthy and did not receive any systematic training before. Participating students and their parents were informed of the purposes and protocol of the study, and written informed assent was obtained from all participants as was written informed consent from their parents or guardians.

Protocol

All the subjects should complete a walking/running incremental load experiment on the treadmill at the speed of 3km/h (walking slowly), 4km/h (walking lightly), 5km/h (walking normally), 6km/h (walking briskly), 7km/h (jogging) and 8km/h (running)with two portable testing instruments, Cosmed K4b2 and ActiGraph GT3X carried on their bodies. They were asked to keep exercising for 5 minutes at each speed without any interval. In addition, after each meal and being fasted for 2 hours, they would receive a 30 min resting test[4].

Cosmed K4b^2

Portable gas metabolic analyzer Cosmed K4b2 (Cosmed, Rome, Italy) (hereinafter was shortened as K4b2) was designed under the principle of indirect calorimetry, which is known as the "gold standard" of measuring the energy expenditure of the body[5], and it has been proved to be effective to measure the oxygen uptake of different activities with different intensities[6]. Researchers strictly acted in accordance with the operation instructions[4] of the instruments when carrying out the testing, and exported the data table and extracted the original VO2 (ml/min) index by analyzing and processing the data randomly equipped by the system.

ActiGraph GT3X

ActiGraph GT3X (Actigraph LLC, Fort Walton Beach, FL) (hereinafter was shorten as GT3X) is a portable three-axis accelerometer, which can automatically collect the data of physical activity like steps/min and so on. GT3X was fixed on the subject's body with an elastic waistband at the junction formed by the right axillary fossa midpoint and the iliac crest level line[6]. It was set in the mode of 60s sampling and three-axis testing. After the experiment, the data would be downloaded by means of ActiLife 5 (ActiGraph R&D and Software Departments) analysis software and the information of steps (steps/min) would be extracted for this study.

Receiver operating characteristic curve

In order to get the Receiver Operating Characteristic curve (shortened as ROC curve),the data of several pairs of Sensitivity and 1-Specificity should be collected by shifting the cut-off points. With the Sensitivity as the vertical axis and the 1-Specificity as the lateral axis, ROC curve was drawn by connecting the collected numbers of different pairs of Sensitivity and 1-Specificity. The area under the curve (AUC) was calculated to determine the diagnostic value. The greater the AUC was, the higher the diagnostic value would be. When the AUC[7] was 0.5 ~ 0.7, the diagnosing accuracy was poor, while 0.7 ~ 0.9 was for fair and 0.9 plus indicated excellent; but when AUC was less than 0.5(AUC<0.5), accurate diagnosing was impossible. The study of critical value through the ROC curve[7] was determined by the corresponding maximum Youden value (Youden value= sensitivity + specificity- 1).

Statistical process of the data

Statistical analysis was completed by means of EXCEL 2007 and SPSS 16.0. Independent Samples T Test was used for the comparison between different genders; the metabolic equivalent (METs) of different sports events equaled (=) the exercise oxygen uptake/resting oxygen uptake, and the steps/min for each exercise was determined by the average steps/min of the third and the fourth minute. An analysis on ROC curve was undertaken with METs as the categorical variable and the steps/min as the testing variable. The diagnosing ability of steps/min on exercise intensity was evaluated by the AUC. When P was less than 0.05(P<0.05), it was regarded as the difference and had statistical significance; the best critical point of steps/min was determined by the maximum Youden value. The exercise intensity was classified into 4 grades: METs<3.0 stood for LPA, 3≦METs<6 for MPV, 6≦METs for VPA[8,9].

RESULTS AND ANALYSIS

Analysis on the steps/min and exercise intensity of different exercises

TABLE 1 indicated that when P was more than 0.05(P>0.05), there was no obvious difference between the adolescents of different genders on steps/min and exercise intensity when they walked/ran. Since when the adolescents did walking/running exercise there was no gender difference on the steps/min and exercise intensity, they could be taken as a whole to be analyzed in this study.

TABLE 1 : Analysis on the steps/min and exercise intensity of different walking/running exercises

Exercise Item	Steps/min			Exercise intensity		
	Male	Female	General	Male	Female	General
3 km/h	54.6±20.3	52.2±19.7	53.4±19.9	2.6±0.6	2.7±0.5	2.6±0.5
4 km/h	101.1±18.0	99.3±15.4	100.2±16.6	2.9±0.6	3.1±0.6	3.0±0.6
5 km/h	119.2±7.6	121.3±4.2	120.3±6.2	3.5±0.7	3.8±0.8	3.6±0.8
6 km/h	128.3±7.5	132.6±5.8	130.5±7.0	4.3±0.9	4.8±1.1	4.5±1.0
7 km/h	159.4±11.5	166.6±8.0	163.1±10.4	6.1±1.2	6.4±1.5	6.2±1.3
8 km/h	163.5±10.3	170.5±8.0	167.1±9.8	6.7±1.4	6.9±1.7	6.8±1.5

Analysis on the diagnostic value of steps/min on exercise intensity

TABLE 2 indicated that steps/min had great diagnostic value to differentiate exercise intensity. The corresponding AUC of 3METs and 6METs was 0.906(P<0.05) and 0.895(P<0.05) respectively, which proved that the steps/min was accurate to diagnose the exercise intensity; moreover, the difference of the data had statistical significance and it further confirmed that steps/min had great diagnostic value to differentiate exercise intensity. Figure 1~2 indicated ROC Curve of Steps/min on 3METs and 6METs.

TABLE 2 : The effectiveness test of diagnosing exercise intensity by steps/min through ROC curve

Exercise Intensity	AUC	Std. Error	Asymptotic Sig.	95%CI	
				Minimum	Maximum
3METs	0.906	0.016	0.000	0.875	0.938
6METs	0.895	0.017	0.000	0.861	0.928

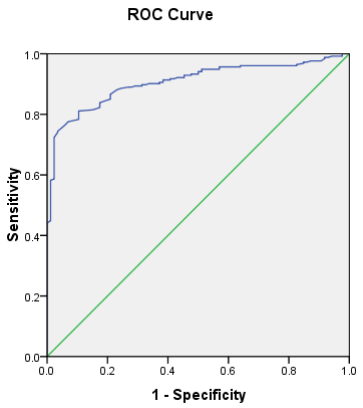

Figure 1 : ROC curve of steps/min for 3METs

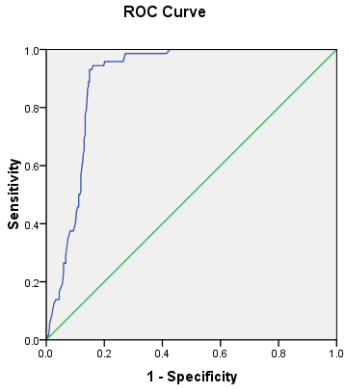

Figure 2 : ROC curve of steps/min for 6METs

Analysis on the best critical value of steps/min

TABLE 3 indicated that when the exercise intensity was 3METs and 6METs, the best critical point of steps/min with corresponding maximum Youden value was 121 steps/min and 144 steps/min respectively. The sensitivity of the best critical point to differentiate the exercise intensity was high（0.744~0.944) and the 1-Specificity was low（0.035~0.160）, which further confirmed the effectiveness of differentiating the best critical point of exercise intensity by steps/min. To the adolescents, the best critical value of MPA was 121 steps/min to 144 steps/min, while it was ≥144 steps/min for VPA.

TABLE 3 : The corresponding steps/min with best critical value for 3METs and 6METs

Exercise Intensity	Sensitivity	Specificity	1 - Specificity	Maximum Youden Value	Steps/min with Best Critical Value
3METs	0.744	0.965	0.035	0.709	121
6METs	0.944	0.840	0.160	0.784	144

DISCUSSION AND CONCLUSION

According to related studies, the amount of exercises done by present Americans was 32% less than that in 1965, and it was expected to be further reduced 46% by 2030. In China, present people's exercise amount reduced 45% compared with that in 1991, and it would reduce 51% by 2030[10]. Similarly, according to *2010 Survey Report of the Medical Examination and Health Status of the Students in Guangzhou City*, only 19% of the students could keep doing exercises one hour per day, which dropped by half compared with 38% in 2005. Some studies also showed that American children reduced the exercise amount with the growth of age. The exercise amount of 15 years old children reduced 75% compared with that of the children at the age of 9[11]; 92% of the children in China did not have extracurricular sports activities[12]. The lack of exercise had become a social problem.

The most direct impacts caused by the lack of exercises were physical decline and the emergence of obesity. There were 5.3 million people dying from related diseases caused by the lack of exercise every year in China, which was even higher than the 5 million deaths caused by smoking. Every year 1.15 million Chinese people died from hypertension[13]; Surpassing India, China became the top country with the largest population of diabetic in the world, and approximately 1/4 of the adults had diabetes or pre-diabetes diseases[14]. In addition, the *Analysis Report about the Testing Data of 2008—2010 National Students' Physical Health Standard* showed that in 2008 the rate of malnutrition, low weight, standard weight, overweight and obesity among the students of different nutritional status accounted for 8.58%, 42.21%, 37.01%, 4.55% and 7.66% respectively, while in 2010, the rate of overweight and obesity increased to 5.05% and 9.41%. According to the *Report of the Sixth National Investigation on Students' Physical Health*, the obesity rate of the adolescents at the age of 7-22 ears old continued to increase, which was 13.33%, 5.64%, 7.83% and 3.78% for the city boys, city girls, rural boys and rural girls correspondingly, increasing 1.94, 0.63, 2.76 and 1.15 percentage respectively compared with those in 2005.

Physical activity had a long-term effect on health and some positive results of healthy habits associated with physical activities often could be extended from childhood to adulthood[15], therefore participating in physical activities in childhood and adolescent period would produce a far-reaching effect for the primary prevention of chronic diseases. Almost all countries had made corresponding guidelines for the adolescent physical activities. For example, in 2008 U.S. Department of Health and Human Service (HHS) issued *2008 American Physical Activity Guidelines*[15], which gave directions on the physical activities done by the adolescents at the age of 6-17 years old: The daily exercise should be as long as 60min and the intensity of the aerobic physical activities should include two grades with the VPA exercise being carried out at least 3 days per week. Furthermore, the types of aerobic physical activities of MPA and VPA were also listed. The 7th document promulgated by the Chinese Ministry of Education in 2007 required that the Sunshine Sports Program should be carried out at school, and when the students were at school, they should allocate at least one hour a day to do physical activities. There existed some disadvantages in these directive documents: first, some activities were not common or unsuitable for Chinese children and adolescents; second, the effects of the physical activities depended on the dose of physical activities applied, which not only included the type, time and frequency of the activities, but also emphasized the importance of the exercise intensity, since different activity forms may produce different exercise intensities even for the same activity.

Walking and running were the basic human activities in daily life. Although they were also very common, they played an important role to human health, which has been proved by scientific researches.

Not requiring a lot on space, infrastructure and skills, they became the most popular physical activities easily mastered by the healthy people. This study proved that steps/min could be used as the effective index to diagnose the intensity of different exercises through the ROC curve; with high sensitivity and low 1-specificity, it was effective to obtain the best critical point of steps/min at low, MPA and VPA through the maximum Youden value. Adolescents should do the walking exercise at the intensity of 121~167 steps/min for at least 60 minutes every day so as to meet the amount requirement of aerobic exercise.

ACKNOWLEDGEMENTS

The research work was supported by MOE (Ministry of Education in China) Project of Humanities and Social Sciences under Grant No.13YJC890050 and the Chinese National Science & Technology Pillar Program (Serial Number: 2009BAK62B01).

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