ACCELERATION ON DIFFERENT BODY POSITIONS DURING RUNNING ON A TREADMILL

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Many fitness index used $\dot{V}O_{2max}$ and heart rate to estimate energy expenditure, but these current methods require expensive equipment for the direct measurement. This study tried to determine a more convenient way to estimate energy expenditure by comparing the relationship of heart rate with acceleration on different positions while running on a treadmill. Eight males (23-32 yr) wore three tri-axial accelerometers, and the placements of accelerometers were left wrist, trunk (low back) and left ankle. Each participant walked for 30 sec at 4 and 6 $km \cdot h^{-1}$, ran 30 sec at 8, 10, 12, 14, 16 $km \cdot h^{-1}$ after they keep stable heart rate in these speeds. All the total accelerations on three placements are significantly correlated with heart rate in this study which indicated that accelerations on human body is a good way to estimate energy expenditure. This information is very useful to develop a new device to accurately estimate energy expenditure using watch which is more convenient compare to current devices in the market.

KEY WORDS: accelerometer, position, treadmill.

INTRODUCTION:

Several attempts have been made to estimate maximal oxygen uptake ($\dot{V}O_{2max}$) outside laboratory due to the requirement of expensive equipment for the direct measurement of maximal oxygen uptake. Such as the 12-min performance test and 20-m shuttle run test (Plasqui & Westerterp, 2005). These tests required minimal equipment but high levels of exertion. Another fitness index to estimate energy expenditure (EE) is heart rate (HR). Crouter, Albright, and Bassett (2005) found out HR is linearly related to oxygen uptake for dynamic activities involving large muscle groups. It can provide a reasonable estimate of energy expenditure during exercise. This information could be useful for athletes and for individuals who exercise for weight control.

Continuing technological advances in physical activity measurement have contributed to increase development and use of various activity monitors (i.e., pedometers and accelerometers) for assessing physical activity in free-living conditions (Rowlands, Stone & Eston, 2007). These devices can be worn on the ankle, wrist, or trunk, and trunk placement (usually the hip) is the most common site for placement (Ward, Evenson, Vaughn, Rodgers & Troiano, 2005). A pedometer is used predominately to assess steps taken during ambulatory activity (i.e., walking and running). An accelerometer measures accelerations and decelerations of movement.

A new sport shoe, Nike+, has been developed to detect physical activity during exercise. A sensor placed under the insole of a Nike+ running shoe which detects the runner's footfalls through its piezoelectric accelerometer. The accelerometer detects when a person's foot is on the ground. When someone is standing still or walking slowly, his feet spend more time touching the ground than in the air. But when jogging or sprinting, his feet spend less and less time on the ground. The faster he runs, the less time his feet spend in contact with the surface under him. According to this basic information of walking and running, a processor can use equations to convert contact time into running speed. The accelerometer also acts as the sensor's on/off switch. When the shoes aren't moving, the accelerometer has no footsteps to report -- it stops sending data. In the absence of the accelerometer's output, the sensor eventually puts itself to sleep. But when a runner puts his shoes on and takes a few steps, the sensor generates electrical pulses, and the sensor resumes operation. The Nike+ iPod sensor sends information to the receiver using a built-in transmitter and antenna. It broadcasts its data at a radio frequency of 2.4 G Hz using a proprietary protocol. In addition

to transmitting data about a person's running stride, it transmits a unique code that it uses to identify itself.
Several studies have reported a strong linear relationship between accelerometer output and speed or energy cost of walking/running in children and adults (Eston, Rowlands & Ingledew, 1998；Nichols, Morgan, Sarkin & Galfas, 1999；Rowlands, Thomas, Eston & Topping, 2004). There is still no device can be worn on the wrist, like watch, to estimate energy expenditure when exercise. Therefore, this study tried to determine a better way to estimate energy expenditure by comparing the relationship of heart rate with acceleration on different positions while running on a treadmill. Especially, determine the viability using the acceleration of hand to estimate energy expenditure while exercising.

METHOD:

Equipment: (1) Crossbow Tri-axial accelerometer is sensitive along three orthogonal axes, which represent mediolateral(X), anteriorposterior(Y), and longitudinal(Z) motion, respectively. A composite measure (resultant vector magnitude, VM) is calculated from $(X^2 + Y^2 + Z^2)^{0.5}$. The accelerometer has a dynamic range of 1-25G (1G = 9.8 $m \cdot s^{-2}$) (2) SensorMedics 2000 Treadmill (Seneormedics Corporation, Anaheim, CA) (3) Polar S625x was used in this study. Polar Electro, Inc., is a leading manufacturer of HR monitor. Their instruments have been shown to provide valid measurements of HR when compared with electrocardiograms.

Data Collection: Eight males (age = 26.2 ± 3.2 yrs; heights = 170.2 ± 5.2 cm; mass = 67.2 ± 7.8 kg) volunteered to take part in this study. Each participant wore three tri-axial accelerometers. The placements were left wrist, trunk (low back) and left ankle. Each participant walked for 30 sec at 4 and 6 $km \cdot h^{-1}$, ran 30 sec at 8, 10, 12, 14, 16 $km \cdot h^{-1}$ after their heart rate in this speed is steady. We hypothesize they keep stable heart rate after it changes no more than three $beats \cdot min^{-1}$ in continuing ten sec after running 60 sec in this speed. Heart rate data is received by Polar S625x and Polar HR transmitter. Sampling rate of accelerometer was 200 $Hz \cdot sec^{-1}$, and acceleration data is collected by Biopac MP 150 and AcqKnowledge Vision 3.8.1.

Data Analysis: Using the average heart rate and acceleration integration in the middle 20 sec of 30 sec. Pearson’s correlation coefficients were calculate to examine the strength of relationship between HR and acceleration integration. The statistical significance level was set at $P < 0.01$, unless otherwise indicated. SPSS version 13.0 (SPSS Inc., Chicago, IL) was used for all statistical analyses.

RESULTS:

All the total accelerations on three placements are significantly correlated with heart rate in this study, even though some individual acceleration in certain directions is not significantly correlated to heart rate. Figure one shows the relationship of HR and acceleration integration in three placements. Table one shows the correlation of acceleration integration with HR.

Table 1: Correlation of acceleration integration with HR

	XYZ	Transverse Plane	Saggital Plane	Frontal Plane	Mediolateral Axis	Anteriorposterior Axis	Longitudinal Axis
Trunk	0.817*	0.568	0.811*	0.824*	0.676	0.292	0.788
Wrist	0.847*	0.663	0.87*	0.79	0.78	0.809*	0.889*
Ankle	0.911**	0.858*	0.911**	0.906**	0.809*	0.839*	0.901**

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

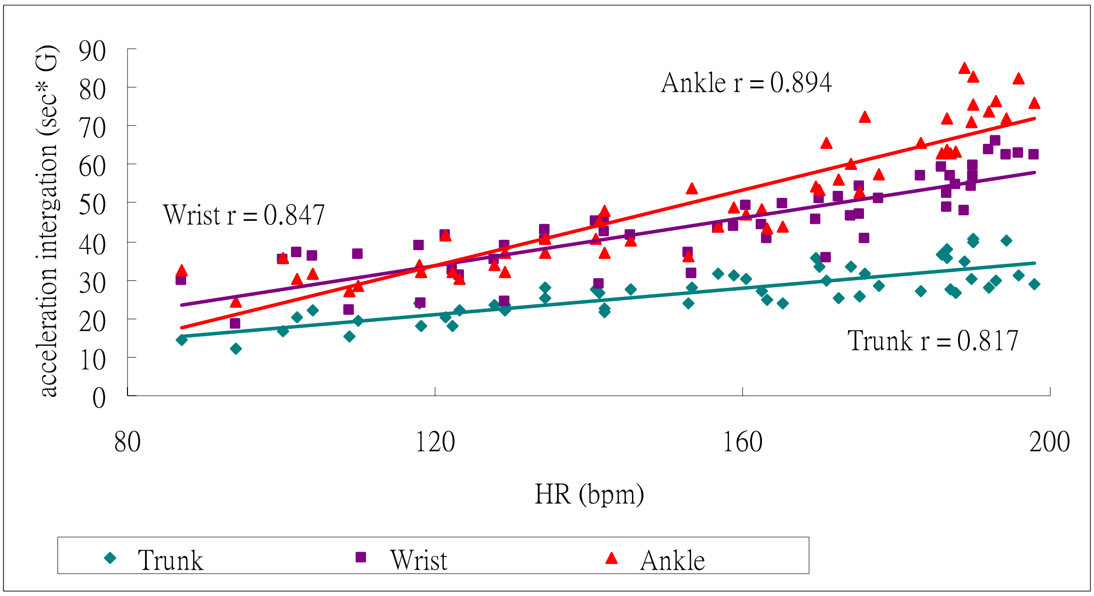

Figure 1: Relationship of trunk, wrist and ankle acceleration integration with HR.

DISCUSSION:

All the total accelerations on three placements are significantly correlated with heart rate in this study. The human body center of mass only moved in a certain range when running on a treadmill even the speed increased, and the slope of treadmill didn't change, so the trunk is not the best placement to estimate heart rate while running on a treadmill compared to the wrist and ankle.

The swing speed and frequency of foot increased as the speed of treadmill increased, so the ankle is a good placement to estimate heart rate in this study. This result prove piezoelectric accelerometer used in Nike+ can accurately detect running speed to estimate energy expenditure while running. But Nike+ iPod sensor sends information to the receiver by a built-in transmitter and antenna which is still not user friendly enough and cost more.

The acceleration of wrist is good to estimate heart rate, too. This result proves using acceleration of wrist can accurately estimate energy expenditure while running. This information is very useful to develop a new device to accurately estimate energy expenditure using watch which is more convenient compare to current devices in the market.

CONCLUSION:

All the total accelerations on three placements are significantly correlated with heart rate in this study which indicated that accelerations on human body is a good way to estimate energy expenditure compared to other methods involved expensive equipment for the direct measurement of maximal oxygen uptake. The accelerations of ankle and wrist are good to estimate heart rate, too. This result proves using acceleration of wrist can accurately estimate energy expenditure while running. This information is very useful to develop a new device to accurately estimate energy expenditure using watch which is more convenient compare to current devices in the market.

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