APPLICABILITY OF A FOREARM-BASED BIOMETRIC SENSOR FOR MEASURING HEART RATE DURING EXERCISE

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ABSTRACT

PURPOSE: The aim of this study was to examine the applicability of a forearm-based accelerometer and optical emitter/sensor to monitor heart rate during exercise. **METHODS:** Forty healthy subjects participated in this study (mean ± SD; 36 ± 11 years, 1.69 ± 0.8 m, 70.7 ± 12.9 kg). Each participant completed a single 8-min treadmill session consisting of standing, walking and running at various intensities. Subjects wore a benchmark chest strap heart rate monitor and a biometric armband on the lateral aspect of the arm with the sensor positioned proximal to the elbow and in line with the thumb. Embedded within the armband was an ultra-miniaturized biometric sensor module comprising an accelerometer, an multi-wavelength optical emitter, an optical detector, and optical lensing. Each trial consisted of the following: 0:30 standing, 0:45 at 3.4 mph walk, 0:45 at 2.2 mph walk, 1:30 at self-selected running speed (5.5 to 9.0 mph), 1:30 at 3.0 mph walk, 1:00 at self-selected running speed (5.5 to 9.0 mph), 0:20 at 2.2 mph walk, 1:40 standing. All data were recorded and averaged over 5 second intervals. **RESULTS:** The trials resulted in exercise of low (42.9% of trials), moderate (27.7% of trials), and vigorous intensities (29.4% of trials). Heart rate during the trials averaged 119 ± 26 b/min and ranged from 59 to 188 beats for the forearm sensor, and 120 ± 27 b/min and ranged from 62 to 190 for the chest strap. The bias for the forearm band was -0.6, LOA of -6 to 5 b/min, and r^2=0.99. There were no significant differences (paired samples t-test) between the devices for heart rate ($p \leq 0.05$) **CONCLUSIONS:** Heart rate assessment via the armband optical sensors was accurate, and limits of agreement within an acceptable range, for heart rate monitoring during exercise as an alternative to chest strap based heart rate monitors.

INTRODUCTION

Heart rate (HR) is one of the most commonly used physiological variables in both the clinical and performance/athletic settings. Through various calculations or assessments, HR is frequently used to prescribe exercise to apparently healthy and diseased populations (Garber et al. 2011) and set intensity thresholds for amateur and professional athletes (Hofmann et al. 1994; Boulay et al. 1997). Over the years, several companies have introduced a direct real-time heart rate monitor (HRM) which consists of a chest strap transmitter and a wrist watch-like receiver (Achten and Jeukendrup 2003). Recently, advancements in technology have allowed for the development of alternative methods for direct, real time, sensors in a form-factor that may provide alternatives to chest strap HRMs. The Rhythm+ from Scosche Industries (Oxnard, CA) uses PerformTek biometric sensor technology, which employs motion- and sunlight-immune reflective photoplethysmography (PPG) in a compact sensor module integrated into an armband for accurately measuring continuous HR. This approach allows the integration of sensor technology into an armband for measuring continuous HR. Moreover, a 3-axis accelerometer within the armband allows for the assessment of movement. To our knowledge, there are a limited number of reports that have examined the accuracy of strapless HRMs. Therefore, **the purpose of the study was to examine the validity of the Rhythm+ sensor to measure continuous HR during dynamic treadmill exercise.**

METHODS

Participants

Forty healthy subjects participated in this study (mean ± SD; 36 ± 11 years, 1.69 ± 0.8 m, 70.7 ± 12.9 kg) volunteered to take part in the study. Prior to commencing the study, all subjects received a detailed explanation of both the benefits and the risks involved with the study, completed a medical history form, and gave written consent.

Procedures

Participants visited the laboratory one time during the study. During preliminary preparation, subjects were asked to stand on the treadmill while the benchmark chest strap (Polar cx800, Polar Electro, Kempele, Finland) was positioned on the chest and the armband (Scosche Industries, Oxnard, CA) on the proximal forearm. The data collected by the chest strap was transmitted via radio frequency to a watch, and armband sensor data were transmitted via Bluetooth signal to a smartphone for collection and exported as a data file for analysis. Following preliminary preparation, the participants were asked to complete a dynamic 8-minute treadmill session involving resting, walking, and running (Table 1). Each device recorded a 5-second average HR for a total of 96 data points per subject during each trial, a total of 3,840 data points for all testing.

Statistical analysis

Pearson product–moment correlation coefficients, bias, 95% limits of agreement, and paired samples T-test were used to examine significant relationships between the armband and chest strap. Validity was assessed using previously established guidelines (Leger and Thiveirge 1988; Terbizan et al. 2002) where HRMs are determined to be valid when the correlation coefficients are > 0.90. Bland-Altman plots were used to determine limits of agreement and bias between devices. Statistical significance was set at P < 0.05 for this investigation.

RESULTS

The trials resulted in exercise of low (42.9% of trials), moderate (27.7% of trials), and vigorous intensities (29.4% of trials) (Figure 1B). Significant positive correlations ($p < 0.05$) were observed between the armband sensor and the chest strap (Figure 1C). There was no significant difference of heart rate between devices ($p < 0.05$). Further examination of 95% confidence intervals and sample distribution (Table 2 and Figure 1) demonstrate validity of the armband sensor.

Table 1 Dynamic treadmill protocol for experimental trials

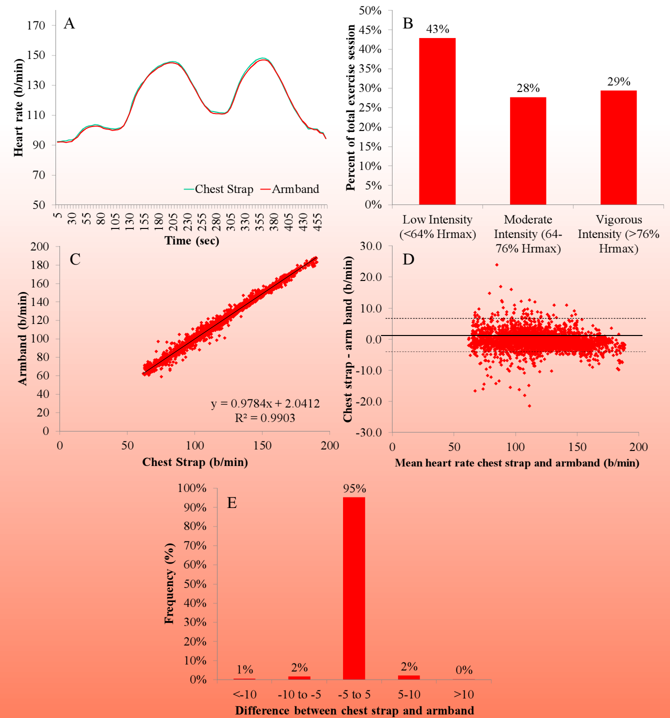
Time (min)	Protocol (speed in mph)
0:00 – 0:30	Standing
0:30 – 1:15	3.4
1:15 – 2:00	2.2
2:00 – 3:30	Self-selected running speed (ranging from 5.5 to 9 mph)
3:30 – 5:00	3.0
5:00 – 6:00	Self-selected running speed (ranging from 5.5 to 9 mph)
6:00 – 6:20	2.0
6:20 – 8:00	Standing

Table 2 Summary statistics for armband heart rate and cadence

	Heart Rate	
	Chest strap	Armband
Mean ± SD	120 ±27	119 ±26
Bias	-0.6	
95% LOA	-6 to 5	
Correlation (R^2)	0.99	

RESULTS-Cont.

Figure 1A-E. Summary of heart rate data (3840 data points). A) Heart rate average for all trials; B) Distribution of exercise intensity; C) regression between armband and chest strap; D) Bland-Altman Analysis; D) frequency distribution.



CONCLUSIONS

An armband based sensor provides a valid measure of heart rate during dynamic treadmill exercise resulting in a wide range of observed heart rates.

High correlations in combination with low LOA during dynamic exercise indicate the Rhythm+ sensing technology is a valid instrument for the measurements of HR.

The armband based sensing technology may be used effectively as an alternative to chest strap monitors for assessment of heart rate.