

A pilot study of using smart clothes for physical workload assessment

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Background and purpose

Work with high-energy metabolism is a known risk factor in working life, which may lead to physical and mental fatigue in short term, and musculoskeletal disorders and overexertion accidents in long term. The International Labour Organization (ILO) has suggested that the average physical workload for an 8-h workday should not exceed 33% of the individual's maximal aerobic capacity, VO_{2max} . Considering the cost and convenience, estimating energy expenditure (EE) from heart rate (HR) has been commonly used in numerous studies. However, HR can be influenced by various factors such as stress, food intake, activity mode and environmental conditions. Especially at low-to-moderate levels of activity, HR is not a good predictor of EE, while pulmonary ventilation has been demonstrated to increase linearly with increased EE at these levels.

Technology innovations have offered opportunities for estimating pulmonary ventilation and energy expenditure using impedance pneumograph with textile electrodes embedded in clothes. In this pilot study, we aim to compare the precision of EE estimated separately by impedance pneumograph and electrocardiograph (ECG) using a smart vest against a reference measurement by indirect calorimetry during simulated working activities.

Study design

The subject was informed of the aims of the study and gave a written consent to participate. The test started with a 20-min resting period in lying position. Then five different simulated work activities were performed, including office work, painting work, postal delivery work, meat cutting work and construction work, each lasted 10 minutes with 5-min breaks in between. Finally, a submaximal test was performed on a treadmill until the subject reached 85% of age-predicted maximal HR. During the tests, oxygen consumption (VO_2) was measured by a computerized metabolic system (Jaeger Oxycon Pro, Germany) with a facemask. ECG and impedance pneumogram were measured by a smart vest with embedded electrodes (developed by University of

Borås, Sweden). Relative measure of pulmonary ventilation (V_{Er}) and HR are extracted from impedance and ECG signal respectively. Individual VO_2/V_{Er} and VO_2/HR relationships were determined during the treadmill test.

Results

In general, EE estimated from V_{Er} (EE_{VE}) had a higher precision than it estimated from HR (EE_{HR}) compared to the reference measurement (EE_{REF}), but the precision was lower during substantial arm movements. The root mean squared error (RMSE) of EE_{VE} compared to EE_{REF} was 2.92 ml/min/kg, and was 3.88 ml/min/kg of EE_{HR} compared to EE_{REF} during all work activities. The percentage error of EE_{VE} (9.1%) was smaller than EE_{HR} (18.7%) compared to EE_{REF} for total EE in five simulated work activities.

Discussion and conclusions

In this study, we introduced a smart textile system for physical workload assessment. The impedance pneumography showed a great potential to estimate pulmonary ventilation and VO_2 during low-to-moderate intensity activities, in comparison to HR monitoring. In the future, to combine the pulmonary ventilation and HR data to improve the precision of the energy expenditure estimation will be explored.

Keywords: Energy expenditure estimation, pulmonary ventilation, heart rate.