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Research Article

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Correlation research on energy consumption under fitness hard and easy intensity based on SWA sensor

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ABSTRACT

Purpose: Use SWA sensor to measure treadmill walk and run as well as spot cycling sports energy consumption, and make comparison with indirect calorimetric testing results, make research on the effectiveness of SWA measurement to energy consumption in fitness, provide reference for sensor correct application. Method: 15 male adults complete 4.8 km/h、6.4 km/h、8.0km/h such 3 speeds walking and running in flat treadmill, and complete 10km/h、13km/L、15km/h indoors spot cycling ,apply SWA(two software visions V6.1、V7.0) and indirect colorimetric method to predict energy consumption in exercising, make matched testing, regression analysis, correlation analysis, Le index as well as consistency check to prediction data. Results:(1) gWA6.1 overestimates energy consumption in treadmill walk and run(1% overestimate)and spot cycle(9% overestimate),but get good correlation and consistency (r =0.91，ICC =0.91). (2)gara sensor predicted fitness energy consumption value far bigger than that by indirect calorimetric method, and the prediction difference would be increased as sports speed increasing, which is different from the sensor old version overestimates easy intensity sports energy consumption and underestimate hard intensity sport energy consumption, but energy consumption that predicted has high correlation and consistency with that by indirect calorimetric.

Key words: Multifunction sensor, indirect calorimetric, validity, fitness, energy consumption

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INTRODUCTION

Fitness is an important part in daily physical movements, its energy consumption testing not only can provide evidence to dynamic lifestyles' evaluation but also helpful for human carry out energy balance management so as to complete fitness quantification objects. Indirect Calorimetric short as IC and Doubly Labeled Water short as DLW have been proofed as the golden standard for energy consumption testing, but due to complicated operation, high cost and other reasons, it is difficult to use them to test large sample crowds free living state energy consumption. At present, energy consumption test equipments and tools tend to develop towards simple and effect direction. Physical movements log is a common method in investigation, but the present research shows that its results have bigger deviation with actual energy consumption and with poor consistence. Sensor techniques has been widely used in the testing of human physical movements energy consumption, provide objective data to acquiring daily physical movements level and energy consumption. Sports sensor is a mechanic or electronic setting, it can response limb or trunk sports condition by fixing on body so that record body displacement data and convert into daily energy consumption value through inner mathematic model. The features of sports sensor is small in size, easy wearing , small influence on daily life, accuracy greatly improved by comparing with physical activities record method, has become common used test tool for free life state energy consumption in recent years [1].

Sense Wear Armband Pr03(short as SWA Pr03) is America Body Media company produced one kind of armlet multifunction sensor, it can dynamic test participants' daily physical activities and sleep behavior relative data. In SWA energy consumption test, its data comes from built-in five sensors, double-shaft accelerated speed sensor, two galvanic skin response sensor, skin temperature sensor and heat flux sensor [2]. Compared with other accelerated

speed sensor, heat flux sensor is one of SWA specific techniques, test heat generation and loss matching with accelerated speed sensor's data can more correctly predict human daily energy consumption value by contrasting with single or double shaft accelerated speed indicators. Except for that, considering that normal accelerated sensor is difficult to make distinguish sit still and do nothing state from slightest physical activities, while SWA can test the changes of skin temperature and galvanic response in easy intensity exercising, so it have an advantage in predicting of easy intensity sports energy consumption .SWA has been widely used in the past 10 years. When test energy consumption in free life state with SWA, underestimate generates by comparing with DLW test method, but the two measurement method have good consistence in daily energy consumption testing. But some research shows that only when participants get higher daily energy consumption, SWA would underestimate energy consumption, while get lower energy consumption, SWA would overestimate energy consumption, similarly, the consistence of the two measurements within the acceptable range (compared with DLW test). When using SWA to test sports energy consumption, every version SWA equipment test data has difference, and energy consumption values calculated by different versions software with the same equipment test data are different. SWA (Pro, V3.2) underestimates most sports energy consumption, but overestimates sports energy consumption major in upper arm. Compare with indirect calorimetric, prediction energy consumption results with formula in software version 3.9and 4.1 have been improved. Some researchers use the same equipment and software version SWA (Pr03, V6.1) as this research, energy consumption has been overestimated in prediction easier intensity sports [3].

From above research results, SWA gets different test results of daily physical activities and sport energy consumption, and its validness to measure energy consumption in fitness is by far unknown. This research takes 15 male adults as research objects, use SWA sensor measured energy consumption in treadmill walk and run as well as spot cycling ,and compared it with indirect calorimetric test results, make research of SWA validness in testing energy consumption in fitness to provide reference for sensor correctly application.

EXPERIMENTAL SECTION

Research objects

Research objects are 15 male adults, their average age is 23years old, the youngest is 20 years old while the oldest is 26years old(Table 1). Through medical history and health checkup, all the participants have not suffered illness in breath system, heart and blood system, endocrine system and etc., their training habits are more than 6h middle intensity movements every week.

Table 1: Research objects general information

N	Age(years old)	height(cm)	weight(kg)	Weight index BMI	Body fat rate (%)
15	23±3	174.2±5.1	68.3±11	22.5±3.4	17±9.4

Research method

Test plan, all test items for participants complete in discontinuous days within one week. First take flat sport platform test, complete cycling test in a week. The two testing orders are completed at random; Sense Wear Pro Armband (SWA) should wear in every testing, meanwhile use portable gas metabolism apparatus to complete indirect calorimetric energy consumption test.12 h before testing, take bland diet, no aggravating activities, no smoking as well as drink any beverage with caffeine. In testing, participants wear comfortable all-cotton sports suits and shoes; take test after stomach empty for 2 to 3 hours.

For flat sports platform test, participants take adaptation movements for 3min in flat sports platform before testing. After test starts, participants hands grip handrail and stand in platform for 5 min to complete resting state data collect, then everyone complete 4.8 km / h(3 mph)、6.4KM / h(4 mph)、8.0km / h(5 mph) three speeds walking , running, slope setting at 0, every speed 6 min, participants not gripping handrail in sports and continuously take 18 min exercises. Flat sports platform's lab temperature is 20℃.7 ± 1.5℃, test environment Q concentration is 23.93%, CQ concentration is 0.03%.

For indoors spot cycling test, cycling test completes in a 90×50 m indoors vacant workshop, floor is made of cement, participants are required to rid in a circle. Before testing, adjust bicycles' saddle, handlebar and pedal location according to every participant stature conditions so as to achieve best ride posture as body slightly fore rake, arms slightly bend. Participants firstly ride bicycles to do adaptation sports 3min. After test starts, every participant first remain resting state 51 min, then everyone carries out 10 km / h、13 km / h 和 15 km / h such three speeds riding according to bicycles stopwatch indication, every two speed intervals rest 1 to 3 min with standard as arrive resting heart rate by break. All participants take the same bicycle to do testing; bicycles are normal handiness bicycle with tier diameter of 26inch and full air inflation.

Test equipment, every time before testing, computer software should be connected and participants personal information (date of birth, height, weight, gender, dominant hand information, smoke or not) should be input into computer, and then wear SWA into participant dominant hand side upper arm's triceps brachii area 5 min in advance and upper arm skin should keep dry before wearing. Every participant should use data line to connect equipment into computer after testing, through Sensewear 6.1 software input data into computer and save as software identifiable swd file, then move on next participant test. Adopt the same heart rate table (Polar, Finland) and indirect measurement equipment in testing. Height testing adopts XINDONG HUATENG CJ-II(auto)height testing equipment, weight adopts high precision digital readout electronics body scale Rcs-16; Body fat content adopts GE double function X ray absorption scanner.

Data handling

Use Sense Wear 6.1 and Sense Wear 7.0 two software versions respectively make calculation of data from swd file that measured by Sense Wear Pro Armband Pr03, read average value of each speed whole journey data from participants resting state, walking and running as well as cycling. Calculate energy consumption per kg weight according to software calculated energy consumption absolute value. Adopt 3B gas metabolism apparatus equipped software Meta—Soft 3.9 to handle collected data, select energy consumption, relative energy consumption and other index, indicate the index mean in 20s time intervals of testing, read average value of each speed whole journey data from participant resting state, walking and running as well as cycling, as Table 2 shows.

Table 2: Research energy consumption in fitness

	Test state	SWA7.0	SWA6.1	IC
Walking running	stand quiet	5.81±0.71	1.39±0.17	1.75±0.28
	4.8 km / h	22.06±4.03	5.26±0.96	4.85±0.75
	6.4 km / h	30.21±6.5	7.18±1.53	6.97±1.00
	8.0 km / h	41.52±7.38	9.91±1.76	10.23±1.33
	average value of 3 speeds	31.26±5.43	7.45±1.29	7.35±0.98
cycling	Sit quiet	5.26±0.71	1.26±0.17	1.90±0.34
	10 km / h	19.99±7.56	4.78±1.81	4.04±0.94
	13 km / h	25.88±8.30	6.19±1.98	5.31±0.81
	15 km / h	25.76±8.60	6.164±2.05	6.32±0.99
	average value of 3 speeds	23.88±6.65	5.71±1.59	5.22±0.88

Note：SWA7.0：SWAPro 3(software V7.0version)；SWA6.1：SWAPro 3(software V6.1)；IC： indirect calorimetry；

In the resting state energy consumption predicting, SWA7.0 comparing with IC prediction value, overestimates 232 %(stand quiet state) and 177 %(sit quiet state) energy consumption. In walking running and cycling, the difference between SWA7.0 and IC predicted energy consumption constant increase as sports speed increasing (overestimate 306%-395%) and that difference in walling running is bigger than that in cycling between SWA7.0 and IC.

In the resting state energy consumption prediction SWA6.1 underestimates 20%(stand quiet state) and 34%(sit quiet state) energy consumption; When prediction walking running and cycling, it has the same difference tendency as IC, both overestimate sports energy consumption in first two speed(walking running is 9% and 3%, cycling is 18% and 17%) and underestimate sports energy consumption at the 3rd speed(walking running is 3%, cycling is 4%).The difference in predicting walking running energy consumption between SWA6.1 and IC (average value is o.3 kcal / min，overestimate l%) less than that of cycling predicting (average value is 1.45 kcal / min，overestimate 9%).

RESULTS AND DISCUSSION

Walking running and cycling is the common fitness style. This research selects normal speed walk(4.8 km/h),brisk walk(6.4 km/h),slow run(8.0 km/h) such 3 common walking running speed and slow speed cycling (10km/h), middle speed cycling (13km/h),fast speed cycling (15km/h) such 3 common riding speed , that reflect fitness normal form to some extent. Use SWA to measure energy consumption in walking running and cycling, that can reflect its energy consumption features when take body building test.

Energy consumption in resting state represents engine body cell mass energy metabolic state, is the most compositions in daily total energy consumption, its accuracy in prediction directly affects the accuracy of daily total energy consumption. SWA7.0 and SWA6.1 show significant difference in testing stand and sit quiet state energy consumption by comparing with IC. Though SWA7.0 overestimate resting state energy consumption (232% and177%), while SWA6.1 underestimates energy consumption at that state (20% and 34%), both the two have good correlation and consistence with IC. In this research results, SWA energy consumption results in resting state

measurement has bigger deviation and against with existed research reports, one reason maybe is the difference on equipment and versions that two research adopts, while the other great important reason is that have connection with too short SWA wear time (just 5min) that participant formally enter into resting state before testing. In research, it mentioned that participant has great data difference in previous 10min, that maybe is SWA each sensors can normal work after longer time adaptation before testing.

SWA6.1 has no significant difference with IC in walking running and cycling sports energy consumption predicting, and with good correlation and consistence, can effectively predict the two sports energy consumption, while SWA6.1 relevant(r) and consistence in predicting walking running energy consumption better than that of cycling. SWA 6.1 overestimates 0.21—0.42 kcal / min(r＝0.79，0.81)energy consumption in measuring normal walk and brisk walk. But as walking running speed improving , SWA 6.1 underestimates slow running 0.33 kcal / rain(3%) energy consumption, and according to existed research results hints, underestimate energy consumption tendency would gradually increase when predict higher speed running (10，08～15.84 km / h).The increase followed by speed ,SWA6.1 underestimate energy consumption may has a connection with that most of participants have perspiration meanwhile as sports intensity increased, skin perspiration influences on SWA built-in heal flux sensor measurement, and accordingly effect SWA prediction formula's accuracy. In cycling prediction, SWA6.1 though total overestimate 9% energy consumption, has no statistics significant difference with IC data, its reason mainly is the difference between cycles ergo meter and spot cycle. In sports energy consumption prediction, SWA mainly rely on built-in accelerated speed sensor, while this kind of sensor tends to underestimate energy consumption when predicts without bearing its own weight sports(as cycling),especially for cycle ergo meter that human don't need to make extra efforts to control balance effects from their own weight, so, SWA underestimate possibility would increase. This research adopts spot cycle test in spacious indoors space, close to actual riding state, participants may have some extra body movements to keep balance in riding that generate SWA6.1 overestimate energy consumption in cycling by comparing with IC.

At present, SWA software version has been upgraded into V7.0, beyond all doubt, energy consumption prediction formula also gets upgraded, but how is the validness in energy consumption predicting by far no research proof. In Soric and others research, researchers mentioned that energy consumption data are in perfect positive correlation by contrast V7.0 and V6.1 data, but not make statistic analysis of the two data.SWA7.0 as Body Media company new promoted software version, by far no research shows its validness and reliability in energy consumption prediction. But through this research, it can be found that though SWA7.0 solves the problem of previous version underestimate sports energy consumption, its predicted energy consumption far bigger than that from IC(difference is 3.36～31.29 kcal / min，overestimate 177%～395%).Present data shows SWA7.0 and SWA6.1 data are almost perfect positive correlated. Except that, SWA7.0 prediction difference with that from IC on walking running and cycling sports energy consumption would be constantly increasing followed by sport speed increasing ,which not the same as SWA6.1 that may be have a connection with manufacturer drastically change energy consumption predicting. However, through SWA7.0 still has advantage in walking running energy consumption predicting than that of cycling , it can be speculated that though manufacturer drastically change formula of energy consumption predicting, maybe just some values, computation principle and model haven't been greatly changed.

Previous studies have already proofed that SWA has an advantage in measuring daily total energy consumption than other accelerometers, and more correctly predict sports energy consumption in easy intensity by comparing with other accelerometers, the main reason is that it is difficult for accelerometers to make distinguish from stay still do nothing state from very slight physical activities, so it may underestimate slightest physical activities energy consumption. In research, both SWA7.0 and SWA6.1 overestimate sports energy consumption in easy intensity exercising, reflects that multiple sensors play some role in energy prediction formula. But due to SWA manufacturer haven't released their energy consumption predicting formula, it is difficult to find out the reason and improvement of overestimate and underestimate occurs from SWA in energy consumption predicting by comparing with IC data. But according to SWA6.1 energy consumption predicting not increase as cycling speed increases, it can be speculated that SWA energy consumption predicting comes from accelerometers data in large extent, while accelerometers measuring functions limited by upper limb small range movements in cycling, therefore, it is difficult to measure that sports load and engine body work have changes under equal body movement range, lead to difference in energy consumption predicting. Future SWA formula can take consideration of adding other sensors (as heat influx) data's weight. The problem has been better improved in SWA7.0 formula.

In addition, this research due to conditions limits has two constraints. First, select 15 male adults as participants and are normal weight mass(BMI is 22.5 ± 3.4), but whether the research results can be applied to other ages mass, overweight and obesity mass even different physical quality level mass, it needs to be further researched to proof. For instance, SWA energy consumption predicting formula including heat influx sensor data, whether prediction

accuracy of energy consumption for overweight and obesity mass would be effect by thicker subcutaneous fat layer in wearing equipment by far is unknown. Second, this research only select platform walking running and spot cycling as the major way of fitness, but whether SWA can correctly predict other styles fitness energy consumption, or greater intensity, long duration sports, different environment sport, all need to be solved in future research.

CONCLUSION

SWA sensors predicted fitness energy consumption value is far bigger than that from indirect calorimetry and the difference of predicted energy consumption would increase as sports speed increases, which is different from the sensor old version overestimates easy intensity sports energy consumption and underestimate hard intensity sport energy consumption, but energy consumption that predicted has high correlation and consistency with that by indirect calorimetry.

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