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Short Communication

Test-retest reliability of a portable gas analysis system under free living conditions

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Abstract

Introduction: K4b^2 (COSMED Srl Italy) is a portable device that is considered valid and reliable for measuring oxygen uptake (VO_2) and carbon dioxide production (VCO_2) under laboratory conditions.

Objectives: Evaluate the test-retest reliability of K4b^2 during walking, stair climbing and descending stairs under free living conditions.

Methods: Twelve participants completed two self-selected comfortable paced walking tests and 20 participants completed two self-selected comfortable paced stair climbing and descending tests. VO_2 and VCO_2 were measured during the tests using K4b^2.

Results: ICCs for VO_2 (ICC & 95% CI: 0.91, 0.72-0.97) and VCO_2 (0.91, 0.72-0.97) of walking demonstrated high reliability whereas reliability was moderate for stair climbing (VO_2: 0.82, 0.6-0.93; VCO_2: 0.73, 0.44-0.88) and low for descending stairs (VO_2: 0.67, 0.33-0.85; VCO_2: 0.51, 0.1-0.77).

Conclusion: K4b^2 is a highly reliable device for VO_2 and VCO_2 measurement during self-paced walking in free living environment.

Introduction

Indirect calorimetry is a criterion measure for energy expenditure of physical activities (1). It involves measurement of oxygen uptake (VO_2) and carbon dioxide production (VCO_2) and subsequent estimation of energy expenditure using modified Weir equation. K4b^2 (COSMED Srl Italy) is a portable electro-medical device that is designed to perform a range of pulmonary function tests including breath by breath measurement of VO_2 and VCO_2 in free living environment (2). Accuracy of K4b^2 has been studied

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under laboratory conditions and is considered a valid and reliable measure of oxygen consumption (3-5). Though the main advantage of the device is its utility in performing measurements in free living environment, few studies have examined its test-retest reliability in non-laboratory settings (6). This study was undertaken to assess test-retest reliability of K4b^2 in measuring VO_2 and VCO_2 during walking, stair climbing and descending stairs in a free living environment.

Methods

Twenty healthy adults with no known medical illness from a university teaching hospital volunteered to participate in the study. All participants were able to walk continuously for more than 10 minutes and used stairs as part of their daily routine. The study protocol was approved by the institutional ethics committee and all subjects provided written informed consent.

Setting and activity

For walking measurements, the participants walked 500 meters along the pavement in an outdoor environment. For stair climbing and descending measurements, the participants descended and climbed four floors in an academic building (total of 96 steps, each of 15 centimeters high and 30 centimeters deep). Self-selected comfortable speed was chosen for all the activities as it is considered to be fairly stable and is reflective of their daily activity pattern (7, 8).

Instrument

Greater details of the device can be found elsewhere (3). In brief, K4b^2 is a lightweight (800 grams) portable device that can be fixed to the participants using an anatomical harness (2). It performs breath-by-breath gas exchange measurement using O_2 and CO_2 analyzers and can be powered by rechargeable batteries. It has a working temperature range of 10°C 40°C, relative humidity range of 20%-80% and an atmospheric pressure range of 700-1060 mBar. The O_2 sensor has a response time less than 150 ms, measurement range between 724% O_2 and an accuracy of ±0.02% O_2. The CO_2 sensor has a response time less than 150 ms, measurement range between 0 8% CO_2 and an accuracy of ±0.01% CO_2.

Testing procedure

After obtaining informed consent, the participants' height and weight were measured in the morning in overnight fasting state. Weight was measured using a digital weighing scale to the nearest 0.1 kg and height measured using a wall mounted stediometer to the nearest millimeter. Prior to testing, the device was warmed up for 45 minutes and its turbine calibrated using a 3 liter syringe. Following this, the O_2 and CO_2 analyzers were calibrated using a reference gas of known concentrations. Prior to each test procedure, the participants were required to refrain from eating, smoking, drinking coffee, tea, energy drinks or alcohol and from vigorous intensity physical activity for a minimum period of two hours. The participants were given time to get familiar in performing the activity with the system attached to them with an anatomical harness and a snug fitting face mask. Heart rate was measured using Polar T31 transmitter and synchronized with gas exchange data. After the system was checked for any air leak around the edges of the facemask, participants walked to the starting point of the test, rested for a couple of minutes and started performing the required activity after completing an air calibration procedure. Data acquisition started immediately after completion of air calibration and the time of crossing the starting and finishing points of each test were noted using a marker switch in the portable unit.

For walking test-retest reliability, 12 of the 20 participants repeated the walking test within one week of the first test. Data from the first minute and last 30 seconds of walking were excluded from analysis so as to obtain a steady state measurement (9). For stair climbing and descending measurements, the participants first descended four floors at their self-selected comfortable speed and sat close to the stairwell for 3-5 minutes. After heart rate and VO_2 values reached resting levels, they ascended four floors at their self-selected comfortable speed. Data collected during the entire duration of descending stairs and entire duration of stair climbing were separately used to obtain the average VO_2 and VCO_2 values for both the activities. The same procedure was repeated in all 20 participants after a rest period

of 7-10 minutes for test-retest analysis.

Data analysis

Data was analyzed using SPSS for Windows, v.15 [Chicago: SPSS Inc]. Paired student *t* test was used to assess within participant difference in atmospheric pressure, temperature, relative humidity, respiratory frequency, respiratory exchange ratio, heart rate, speed and gas exchange parameters of VO_2 and VCO_2 between first and second tests for all three activities. Intraclass correlation coefficient (ICC) for VO_2 and VCO_2 was computed using data obtained from first and second test for all three activities using a two-way mixed effect model for consistency of single measure. An ICC $\geq$ 0.9 was considered as highly reliable, ICC between 0.7 0.89 was considered as moderately reliable and an ICC < 0.7 was considered as having low reliability. A 2-tailed p value of < 0.05 was considered as significant for both paired difference and ICC.

Results

Six males and six females with the following demographics participated in the walking test-retest reliability study: Average (±SD) age of 26.4 (±3.7) years, height of 165.5 (±8.6) centimeters, weight of 59.3 (±9.9) kgs and body mass index of 21.4 (±2.1). Nine males and 11 females with the following demographics participated in the stair ascending and descending test-retest reliability study: Average (±SD) age of 27.9 (±4.6) years, height of 163.9 (±8.3) centimeters, weight of 58.3 (±8.1) kg and body mass index of 21.6 (±1.9).The variables of atmospheric pressure, temperature, relative humidity, respiratory frequency, respiratory exchange ratio, heart rate and speed were not significantly different between the first and second tests for walking and stair climbing. For descending stairs though, the difference between first and second tests for respiratory exchange ratio, heart rate and speed of coming down stairs was significantly different ($p \leq 0.01$). Difference in VO_2 and VCO_2 values between the first and second tests for walking, stair climbing and descending stairs and their ICC are summarized in Table I. Test-retest reliability of VO_2 and VCO_2 was high for walking, moderate for stair climbing and low for descending stairs.

Discussion

This is the first study to assess the test-retest reliability of VO_2 and VCO_2 measurements using K4b² in healthy individuals during walking, stair climbing and descending stairs under free living condition. K4b² is considered a light weight portable devices

TABLE I: Test-retest reliability of VO_2 and VCO_2 measurements during walking, stair climbing and descending stairs.

	Walking test 1	*Walking test 2*	*Stair climbing test 1*	*Stair climbing test 2*	*Descending stairs test 1*	*Descending stairs test 2*
	N=12		*N=20*		*N=20*	
VO_2 ml/minute Mean±SD	967.1±208.8	958.1±235.9	1212.8±204.7	1250.7±271.7	619.2±118.1	657.4±140.4
VO_2 Mean Difference±SD, (Range) [Significance]	9±95 (–220.3, 173.9) [NS, p=0.748]		–37.8±143.5 (–360.5, 335.5) [NS, p=0.253]		–38.2±106. (–223.3, 318) [NS, p=0.123]	
ICC for VO_2 (95% CI)	0.91* (0.72, 0.97)		0.82* (0.6, 0.93)		0.67* (0.33, 0.85)	
VCO_2 ml/minute Mean±SD	734±141.2	732.3±202.9	863.1±145.9	846.3±170.3	516±130.7	604.2±129.8
VCO_2 Mean Difference±SD, (Range) [Significance]	1.7±74.4 (–195.4, 91.2) [NS, p=0.937]		16.8±116.3 (–222.6, 347.9) [NS, p=0.527]		–87.3±129.1 (–243.8, 376.8) [Significant, p=0.007]	
ICC for VCO_2 (95% CI)	0.91* (0.72, 0.97)		0.73* (0.44, 0.88)		0.51** (0.1, 0.77)	

Abbreviations:
VO_2, Oxygen consumption; VCO_2, Carbon dioxide production; NS, Not significant; ICC, Intraclass correlation coefficient; CI, Confidence interval
*p<0.001, **p<0.01

and previous studies have shown that wearing the device does not impair test performance.

Prior to this study, only one study assessed and established high reliability of this device during over-ground walking measurements in chronic stroke survivors (6). Our study showed that VO_2 and VCO_2 measurements using K4b^2 had high test-retest reliability for a steady state activity like walking and moderate to low test-retest reliability for non-steady state activities like climbing and descending stairs. It has previously been shown that achievement of steady state is essential to reduce the error of measurement during indirect calorimetry (9, 10). In our study, achievement of steady state condition was possible for walking but not for climbing and descending stairs. During climbing and descending stairs, the presence of three landing areas between each floor resulted in frequent changes in intensity of activity. This frequent change in intensity of activity limits the possibility of achieving a steady state of gas exchange. In addition, the duration required to climb and descend stairs (57-96 seconds) was less than the minimum recommended duration of three minutes of steady state activity required for reliable measurements. Both these factors could have resulted in lower test-retest reliability during climbing and descending stairs. Another important factor affecting test-retest reliability is the similarity between both the tests. Though we were able to achieve similarity between tests for important confounding variables like environmental parameters, speed, heart rate and respiratory exchange ratio for walking and stair climbing tests, similarities of speed, heart rate and respiratory exchange ratio between two tests could not be achieved for descending stairs. This lack of similarity between tests occurred despite sufficient practice trials and test performance by participants at their self-selected comfortable speed. Future studies need to plan adequate safeguards to overcome this problem.

Our findings highlight that despite biological variability and testing under free living environment, test-retest measures using K4b^2 are highly reliable when tests are performed in a similar manner. If similarity in testing conditions is maintained, K4b^2 can be used to measure effect of interventions on VO_2 and VCO_2 in free living environment.

Conclusion

K4b^2 is a highly reliable device for measuring VO_2 and VCO_2 during walking under free living conditions. However, its reliability for non-steady state and short duration activities like stair climbing and descending stair under free living conditions needs to be studied further.

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