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COSMED Homepage

<http://www.cosmed.com>

K5 Page

<http://www.cosmed.com/wearit>

K5

General

Validity, reliability and minimum detectable change of COSMED K5 portable gas exchange system in breath-by-breath mode*C. Baldari, M. Meucci, F. Bolletta, M.C. Gallotta, G.P. Emerenziani, L. Guidetti - PLoS ONE, December 2018, Volume 13, Issue 12.*

AIM: To examine the validity, reliability and minimum detectable change (MDC) of the Cosmed K5 in breath by breath (BxB) mode, against VacuMed metabolic simulator. Intra and inter-units reliability was also assessed.

METHODS: Fourteen metabolic rates (from 0.9 to 4 L.min⁻¹) were reproduced by a VacuMed system and pulmonary ventilation (VE), oxygen consumption (VO₂) and carbon dioxide production (VCO₂) were measured by two different K5 units. Validity was assessed by ordinary least products (OLP) regression analysis, Bland-Altman plots, intraclass correlation coefficients (ICC), mean percentage differences, technical errors (TE) and MDC for VE, VO₂, and VCO₂. Intra- and inter-K5 reliability was evaluated by absolute percentage differences between measurements (MAPE), ICCs, TE, and MDC.

RESULTS: Validity analysis from OLP regression data and Bland-Altman plots indicated high agreement between K5 and simulator. ICC values were excellent for all variables (>0.99). Mean percentage differences in VE (-0.50%, p = 0.11), VO₂ (-0.04%, p = 0.80), and VCO₂ (-1.03%, p = 0.09) showed no significant bias. The technical error (TE) ranged from 0.73% to 1.34% (VE and VCO₂ respectively). MDC were lower than 4% (VE = 2.0%, VO₂ = 3.8%, VCO₂ = 3.7%). The intra and inter K5 reliability assessment revealed excellent ICCs (>0.99), MAPE < or around 1%, MDC < or around 3%.

Table: Intra- and inter-system K5 reliability.

| | Intra-K5 system reliability | | | | |
|--|-----------------------------|------|------------------------|------|------|
| | MAPE (95% CI) | p | ICC (95% CI) | TE | MDC |
| VE (L.min ⁻¹) | 0.66 (0.08 to 1.23) | 0.90 | 1000 (1.000 to 1.000) | 0.71 | 1.96 |
| VO ₂ (mL.min ⁻¹) | 1.11 (0.44 to 1.78) | 0.41 | 0.999(0.997to 1.000) | 0.82 | 2.28 |
| VCO ₂ (mL.min ⁻¹) | 1.16 (0.86 to 2.37) | 0.98 | 0.999 (0.997to 1.000) | 0.93 | 2.57 |
| | Inter-K5 system reliability | | | | |
| | MAPE (95% CI) | p | ICC (95% CI) | TE | MDC |
| VE (L.min ⁻¹) | 0.99 (0.41 to 1.58) | 0.73 | 1000 (0.999 to 1.000) | 0.72 | 1.99 |
| VO ₂ (mL.min ⁻¹) | 1.36 (0.91 to 1.81) | 0.65 | 0.999 (0.997 to 1.000) | 1.15 | 3.19 |
| VCO ₂ (mL.min ⁻¹) | 1.85 (1.35 to 2.35) | 0.68 | 0.998 (0.995 to 0.999) | 1.18 | 3.28 |

CONCLUSION: K5 in BxB mode is a valid and reliable system for metabolic measurements. This is the first study assessing the MDC accounting only for technical variability reporting intra- and inter-units MDCs <3.3%

Accuracy and Precision of the COSMED K5 Portable Analyser*I. Perez-Suarez, M. Martin-Rincon, J.J. Gonzalez-Henriquez, C. Fezzardi, S. Perez-Regalado, V. Galvan-Alvarez, J.W. Juan-Habib, D. Morales-Alamo, J.A.L. Calbet – Frontiers in Physiology, December 2018, Volume 9, Article 1764.*

AIM: To determine the accuracy of the portable metabolic cart K5 by comparison with a stationary metabolic cart (Vyntus CPX), and to assess the reliability of K5 during prolonged walks in the field.

METHODS: Two different studies were carried out to assess validity and reliability on two different groups separately. The validity of the COSMED K5 was determined by comparison with the Vyntus CPX both at rest and during submaximal exercise on a cycle ergometer. The reliability of the COSMED K5 was assessed by measuring ergospirometric variables and the energy expenditure during prolonged walks (13 km). Values were checked for normal distribution using the Shapiro-Wilks test. The agreement between methods was assessed by determining the bias in absolute values and as a percentage of the measured value with the reference method (Vyntus) other than by the Concordance Correlation Coefficient. The accuracy of COSMED K5 measurements was evaluated using Student t-test whereas the reliability was assessed by determining the CV.

RESULTS: During measurements at rest and 60 W Vyntus and COSMED K5 reported similar mean $\dot{V}O_2$, $\dot{V}CO_2$, RER, and energy expenditure values. At rest and during low intensity exercise the B×B mode is more accurate whereas when the aim of the study is to measure $\dot{V}O_2$ or substrate oxidation at high exercise intensities the mixing chamber mode is preferable.

CONCLUSION: K5 is an excellent portable metabolic cart which is almost as accurate as a state-of-art stationary metabolic cart, capable of measuring precisely energy expenditure in the field and showing a reliable performance during more than 2 h of continuous work.

Open-Circuit Respirometry: A Historical Review of Portable Gas Analysis Systems

Macfarlane DJ. Eur J Appl Physiol. 2017 Oct 17.

“The option of dual measurement allows users to undertake more conventional steady-state metabolic measurements via the dynamic mixing chamber, or to examine kinetics during transients, permitting greater versatility by allowing users to mitigate criticisms of either sampling method.”

Portable open-circuit spirometry systems: a review.

Overstreet BS, Bassett DR Jr, Crouter SE, Rider BC, Parr B.-J Sports Med Phys Fitness. 2016 Feb 10.

“The newest version of one of the portable systems (Cosmed K5) now provides researchers the option of using either micro-proportional sampling or breath-by-breath techniques within the same system. This new development challenges the prevailing view, which holds that the breath-by-breath technique is the more advanced and desirable method in all situations. In our view, the breath-by-breath method is potentially subject to more errors due to alinearity of the sensors and temporal mis-matching of ventilation and gas fractions.[...] The Cosmed K5 will provide an opportunity, for the first time, for researchers to compare the validity and reliability of these two techniques within the same device.”

K4 b²

General

Validation of the COSMED K4 b2 portable metabolic system.

McLaughlin JE, King GA, Howley ET, Bassett DR Jr, Ainsworth BE. Int J Sports Med. 2001 May;22(4):280-4.

PURPOSE: The purpose of this investigation was to assess the accuracy of the COSMED K4 b2 portable metabolic measurement system against the criterion Douglas bag (DB) method.

METHODOLOGY: During cycle ergometry on consecutive days, oxygen consumption (VO₂), carbon dioxide production (VCO₂), minute ventilation (VE), and respiratory exchange ratio (R) were measured at rest and during power outputs of 50, 100, 150, 200, and 250W.

RESULTS: No significant differences ($P > 0.05$) were observed in VO₂ between the K4 b2 and DB at rest and at 250W. Though the K4 b2 values were significantly higher ($P < 0.05$) than DB values at 50, 100, 150, and 200 W, the magnitude of these differences was small (0.088, 0.092, 0.096, and 0.088 L x min⁻¹, respectively). VCO₂ and VE values from the K4 b2 were significantly lower than the DB at 200 and 250 W, while no significant differences were observed from rest through 150W. The slight overestimation of VO₂ (50-200 W) combined with the underestimation of VCO₂ (200 and 250W) by the K4 b2 resulted in significantly lower R values at every stage.

CONCLUSIONS: These findings suggest the COSMED K4 b2 portable metabolic measurement system is acceptable for measuring oxygen uptake over a fairly wide range of exercise intensities.

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

Sundar Kumar Veluswamy, Vasudeva Guddattu and Arun G. Maiya. Indian J Physiol Pharmacol 2015; 59(1): 117–120

PURPOSE: Evaluate the test-retest reliability of K4b2 during walking, stair climbing and descending stairs under free living conditions.

METHODOLOGY: Twelve participants completed two self-selected comfortable paced walking tests and 20 participants completed two self-selected comfortable paced stair climbing and descending tests. VO₂ and VCO₂ were measured during the tests using K4b2.

RESULTS: ICCs for VO₂ (ICC & 95% CI: 0.91, 0.72-0.97) and VCO₂ (0.91, 0.72-0.97) of walking demonstrated high reliability whereas reliability was moderate for stair climbing (VO₂: 0.82, 0.6-0.93; VCO₂: 0.73, 0.44-0.88) and low for descending stairs (VO₂: 0.67, 0.33-0.85; VCO₂: 0.51, 0.1-0.77).

CONCLUSIONS: K4b2 is a highly reliable device for VO₂ and VCO₂ measurement during self-paced walking in free living environment.

Validity and reliability of a new portable telemetric calorimeter designed to measure oxygen consumption and carbon dioxide production.

De Lorenzo A, Sorge RP, Bertini I, Andreoli A, Iacopino L, Di Daniele N, Perriello G. Diabetes Nutr Metab. 2001 Oct;14(5):268-76.

PURPOSE: The purpose of the present study was to evaluate the precision and the accuracy of a new portable telemetric calorimeter developed for the measurement of oxygen consumption, carbon dioxide production and pulmonary ventilation.

METHODOLOGY: An experimental protocol was designed to generate a series of tidal volumes (from 100 ml to 6000 ml at 200 ml steps) at different respiratory rates (5, 8, 14, 20, 40, 60, 75 breaths-min⁻¹). For this purpose, a standardized pulmonary waveform generator system was utilized. Moreover, in order to evaluate the measure of O₂ and CO₂ concentrations at different temperatures (-10 degrees, 0 degrees, 15 degrees, 25 degrees, 40 degrees C), the instrument was placed inside an adjustable temperature and humidity chamber.

RESULTS: The accuracy of flow measurements was within +/-3% in respect to the real values throughout the entire range of physiological values, whereas the measurements of gas concentrations were within +/-1% between 0 and 25 degrees C.

CONCLUSIONS: The new portable telemetric calorimeter represents an easy to use instrument for the measure of energy expenditure during the activities of daily living.

Running

K4b2 Validity and Reliability during Fast Outdoor Running

Ramzy Ross, Barry Fudge, Alexander Gibson, Robert Ojiambo, Yannis Pitsiladis. Medicine & Science in Sports & Exercise: May 2011 - Volume 43 - Issue 5 - p 80

INTRODUCTION: The portable K4b2 (K4b2, COSMED s.r.l., Rome, Italy) was designed to measure breath-by-breath pulmonary gas exchange in the field. K4b2 validity has been confirmed during treadmill running, while during outdoor running the K4b2 systematically underestimated oxygen uptake (VO₂) (Fudge et al, MSSE, 2008).

PURPOSE: This study assessed both the validity and reliability of the K4b2 with the introduction of an automated periodical recalibration in an attempt to correct the systematic underestimation in VO₂ previously reported.

METHODS: 19 Caucasian endurance trained individuals and 30 adolescents (boys, n=15; girls, n=15) from a rural Nandi primary school in Kenya completed maximal incremental running tests. Tests involved 3 minute exercise bouts at running speeds between 8 to 22 km·hr⁻¹ in 2 km·hr⁻¹ increments. Gas exchange parameters were recorded throughout. The Douglas bag method (DB) was used as the criterion for comparison.

RESULTS: K4b2 measurements were not significantly different for VO₂ throughout all submaximal and maximal running speeds when compared to DB: corresponding to a K4b2 mean bias (MB) -31 ml·min⁻¹ with limits of agreement (LOA) -430 to 492 ml·min⁻¹ for all running speeds. K4b2 test-retest reliability was also demonstrated with no significant differences found in all measured gas exchange variables throughout all submaximal and maximal running speeds: corresponding to a K4b2 MB -31 ml·min⁻¹ with LOA -535 to 473 ml·min⁻¹ for all running speeds.

CONCLUSION: As a result of the introduction of an automated calibration, the K4b2 device proved valid and reliable for VO₂ during submaximal and maximal running velocities outdoors.

The level of accuracy and agreement in measures of FE_{O2}, FE_{CO2} and VE between the Cosmed K4b2 portable, respiratory gas analysis system and a metabolic cart.

Pinnington HC, Wong P, Tay J, Green D, Dawson B. J Sci Med Sport. 2001 Sep;4(3):324-35.

PURPOSE: This study aimed to assess the accuracy of the Cosmed K4b2 (Cosmed, Italy) portable metabolic system that measures FE_{O2}, FE_{CO2} and VE on a breath by breath basis.

METHODOLOGY: For gas concentration comparisons, expired air from 20 subjects performing treadmill running was collected in a 600 litre chain compensated Collins Tissot tank and analysed for FE_{O2} and FE_{CO2} using a laboratory metabolic cart and the Cosmed K4 b2 metabolic system. For ventilation comparisons, serial steady state VE (STPD) values were measured on 10 subjects using the Cosmed K4b2 ventilation turbine and a Morgan ventilation monitor during a continuous treadmill running protocol at ascending speeds of 8, 11 and 14 km x h⁻¹.

RESULTS: The Cosmed K4b2 FE_{O2} and FE_{CO2} measures were significantly lower ($P < 0.001$) than the metabolic cart values. Pearson correlation coefficients (r) and the standard error of measurement (SEM) demonstrated a high association between the Cosmed and the metabolic cart measures (FE_{O2} $r = 0.971$, SEM 0.071; FE_{CO2} $r = 0.925$, SEM 0.087). Cosmed VE (l x min⁻¹) measures were significantly greater than Morgan values at running speeds of 8 kmh⁻¹ ($P < 0.001$) and 11 kmh⁻¹ ($P < 0.001$) but not significantly different at 14 km x h⁻¹ ($P > 0.05$). When VE measures at the three running speeds were combined, the mean difference between instrument measures ranged between 3.5 - 4.0 l x min⁻¹ but the values were highly correlated ($r = 0.982$, $P < 0.01$; SEM 3.03). Linear regression analysis revealed the following regression equations to predict metabolic cart values from Cosmed measures: FE_{O2} = 0.852+0.963 Cosmed ($R^2 = 0.940$, $P < 0.001$), FE_{CO2} = 0.627+0.878 Cosmed ($R^2 = 0.856$, $P < 0.001$), VE = -2.50+0.984 Cosmed ($R^2 = 0.965$, $P < 0.001$).

CONCLUSIONS: The results indicated that the Cosmed K4b2 unit assessed here produced measures of FE_{O2}, FE_{CO2} and VE that had strong correlation to values obtained from a metabolic cart. However, linear regression analysis may further improve the accuracy of Cosmed K4b2 measures when compared to metabolic cart values.

Comparative analysis of the Cosmed Quark b2 and K4b2 gas analysis systems during submaximal exercise.

Eisenmann JC, Brisko N, Shadrick D, Welsh S. J Sports Med Phys Fitness. 2003 Jun;43(2):150-5.

PURPOSE: The purpose of this study was to compare the Cosmed K4b2 portable gas analysis system with the Cosmed Quark b2 metabolic cart.

METHODOLOGY: Twenty-one subjects attended one testing session that consisted of duplicate measurements of gas volumes and concentrations using both Cosmed gas analysis systems at 3 treadmill work rates; 1) 80m x min⁻¹, 0% grade, 2) 80m x min⁻¹, 5% grade, and 3) 80m x min⁻¹, 10% grade. Subjects walked for 3 min at each rate with one of the gas analysis systems attached to the facemask. The order of the procedures was randomized so that one system was used during both phases (1st or 2nd) of each work rate.

RESULTS: The results indicated that oxygen consumption (VO_2) was significantly higher in the K4b2 compared to the Quark at $80\text{ m} \times \text{min}^{-1}$, 0% grade (14.3 ± 1.2 vs 13.6 ± 1.2 $\text{ml} \times \text{kg}^{-1} \times \text{min}^{-1}$, respectively), ($p < 0.01$). The fractional concentration of oxygen in expired air was also significantly lower in the K4b2 at $80\text{ m} \times \text{min}^{-1}$, 0% grade and $80\text{ m} \times \text{min}^{-1}$, 10% grade ($p < 0.05$). There were no significant differences between systems for minute ventilation or carbon dioxide production. Despite the small mean bias in mean VO_2 values (0.5 - 1.0 $\text{ml} \times \text{kg}^{-1} \times \text{min}^{-1}$ higher) in the K4b2, all individual values were within the limits of agreement (mean difference ± 2 SD) as determined by the Bland-Altman technique.

CONCLUSIONS: The findings show a minimal bias in respiratory and metabolic parameters during bi-pedal locomotor activities at low to moderate exercise intensities in the two gas analysis systems.

Walking

Within and between-day reliability of energetic cost measures during treadmill walking

Audra Davidson, Emily S. Gardinier & Deanna H. Gates. Cogent Engineering Volume 3, 2016 - Issue 1

PURPOSE: The efficacy of assistive devices used during walking is often measured as a reduction in metabolic cost. Metabolic cost is typically assessed within a day or on multiple days, yet the benefit of performing within-day vs. between-day metabolic assessments is unknown. The purpose of this study was to determine the within-day minimal detectable change of standard measures of physiologic performance using a conventional portable metabolic system (K4b2 Cosmed, Rome, Italy), and compare these to between-day values.

METHODOLOGY: Twenty healthy adults completed two identical data collection sessions on separate days. In each session they performed three bouts of treadmill walking interspersed with three bouts of rest while oxygen consumption (VO_2 , VO_2), carbon dioxide production, and heart rate were measured. Intraclass correlation coefficients (ICC) and minimal detectable change values were calculated for non-resting within-day, as well as all between-day comparisons.

RESULTS: All within-day measures were clinically reliable ($\text{ICC} > 0.96$), while between-day measures were generally less reliable ($\text{ICCs} > 0.82$). Within-day minimal detectable change values (walking heart rate = 4.9 bpm; gross VO_2 - VO_2 = 0.80 mL/kg/min ; net VO_2 = 0.80 mL/kg/min ; cost of transport = 0.022 J/Nm) were about half as large as between-day values.

CONCLUSIONS: The K4b2 system is able to detect small changes in physiologic measurements within a day. Within-day MDCs were about half the size of between-day values. These results emphasize the benefit of using within-day methodological designs when feasible as the ability to determine differences in metabolic cost dramatically improves.

Comparison of the Cosmed K4b2 Portable Metabolic System in Measuring Steady-State Walking Energy Expenditure

Jennifer A. Schrack, Eleanor M. Simonsick, and Luigi Ferrucci. PLoS One. 2010; 5(2): e9292.

PURPOSE: Recent introduction of the Cosmed K4b2 portable metabolic analyzer allows measurement of oxygen consumption outside of a laboratory setting in more typical clinical or household environments and thus may be used to obtain information on the metabolic costs of specific daily life activities. The purpose of this study was to assess the accuracy of the Cosmed K4b2 portable metabolic analyzer against a traditional, stationary gas exchange system (the Medgraphics D-Series) during steady-state, submaximal walking exercise.

METHODOLOGY: Nineteen men and women (9 women, 10 men) with an average age of 39.8 years (± 13.8) completed two 400 meter walk tests using the two systems at a constant, self-selected pace on a treadmill. Average oxygen consumption (VO_2) and carbon dioxide production (VCO_2) from each walk were compared.

RESULTS: Intraclass Correlation Coefficient (ICC) and Pearson correlation coefficients between the two systems for weight indexed VO_2 (ml/kg/min), total VO_2 (ml/min), and VCO_2 (ml/min) ranged from 0.93 to 0.97. Comparison of the average values obtained using the Cosmed K4b2 and Medgraphics systems using paired t-tests indicate no significant difference for VO_2 (ml/kg/min) overall ($p = 0.25$), or when stratified by sex ($p = 0.21$ women, $p = 0.69$ men). The mean difference between analyzers was -0.296 ml/kg/min (± 0.26). Results were not significantly different for VO_2 (ml/min) or VCO_2 (ml/min) within the study population ($p = 0.16$ and $p = 0.08$, respectively), or when stratified by sex (VO_2 : $p = 0.51$ women, $p = 0.16$ men; VCO_2 : $p = .11$ women, $p = 0.53$ men).

CONCLUSIONS: The Cosmed K4b2 portable metabolic analyzer provides measures of VO_2 and VCO_2 during steady-state, submaximal exercise similar to a traditional, stationary gas exchange system.

Test–Retest Reliability and Minimum Detectable Change Using the K4b2: Oxygen Consumption, Gait Efficiency, and Heart Rate for Healthy Adults During Submaximal Walking

Benjamin J. Darter, Kelly M. Rodriguez, and Jason M. Wilken. Res Q Exerc Sport. 2013 Jun; 84(2): 223–231.

PURPOSE: Oxygen consumption (VO₂; mL O₂/kg/min), gait efficiency (GE; mL O₂/kg/m) and heart rate (HR; beats per minute) are measures of physiological gait performance. However, the collection device, procedures for data normalization, and biological factors can affect measurement variability. The purpose of this study was to determine the test–retest reliability and minimum detectable change (MDC) for VO₂, GE, and HR with the K4b2 at submaximal walking speeds in healthy young adults. A second purpose was to determine if net measures improved reproducibility.

METHODOLOGY: Twenty-two participants completed 2 identical treadmill tests on separate days at submaximal walking speeds from 0.71 m/s to 1.65 m/s.

RESULTS: Intraclass correlation coefficient (ICC) values for gross VO₂, gross GE, and HR were greater than .85 for all walking speeds. Associated MDC values were approximately 7% to 10% for gross VO₂ and GE, and approximately 9% to 12% for HR. ICC values for resting VO₂ were lower, with MDC values approaching 25%. Subtracting out resting values to derive net VO₂ and GE values produced ICC values below .76 for the 2 slowest speeds but ICC values greater than .83 for the faster speeds. MDC values for net VO₂ and GE were up to 20% for the slowest speeds.

CONCLUSIONS: The results demonstrate metabolic cost can be assessed reliably using the K4b2 during submaximal walking and that gross measures are more reliable than net measures. Furthermore, changes at self-selected speeds exceeding 1.0 mL O₂/kg/min in gross VO₂ and 0.01 mL O₂/kg/m in gross GE can be considered a true change in walking performance.

Clinical

Test-retest reliability of portable metabolic monitoring after disabling stroke.

Stokey AD, McCusker MG, Sorkin JD, Katzel LI, Shaughnessy M, Macko RF, Ivey FM. Neurorehabil Neural Repair. 2013 Nov-Dec;27(9):872-7.

PURPOSE: Impaired economy of gait, prevalent in chronic stroke secondary to residual gait deficits, is associated with intolerance for performing activities of daily living. Gait economy/efficiency is traditionally assessed by determining the rate of oxygen consumption during submaximal treadmill walking. However, the mechanics and energetics of treadmill versus overground walking are very different in stroke survivors with ambulatory deficits. Clearly, overground cardiopulmonary measures are needed to accurately profile movement economy after stroke. An obstacle to obtaining such measures after stroke has been the absence of reliable portable metabolic monitoring equipment. The purpose of this study was to establish the test-retest reliability of a portable metabolic monitoring device during overground walking in hemiparetic stroke survivors.

METHODOLOGY: Twenty-three chronic hemiparetic stroke survivors underwent two 6-minute walk tests while wearing a COSMED K4b(2) portable metabolic measurement system. Intraclass correlations coefficients (ICC) were calculated for both cardiopulmonary parameters and distance covered to determine test-retest reliability. An ICC of ≥ 0.85 was considered reliable.

RESULTS: ICCs for relative Vo₂ (0.90), absolute Vo₂ (0.93), Vco₂ (0.93), and minute ventilation (0.95) demonstrated high reliability, but not for heart rate (0.76) or respiratory exchange ratio (0.64). There was no significant difference in the distance each participant walked between the first and second tests, eliminating distance as a potential confounder of our analyses (ICC = 0.99).

CONCLUSIONS: Our results strongly support the reliability of the K4b(2) for quantifying overground gait efficiency after stroke. Use of this device may enable researchers to study how varying poststroke rehabilitation interventions affect this central measure of health and function.

Swimming (with Aquatrainer)

AquaTrainer® Snorkel does not Increase Hydrodynamic Drag but Influences Turning Time.

Ribeiro J, Figueiredo P, Guidetti L, Alves F, Toussaint H, Vilas-Boas JP, Baldari C, Fernandes RJ. Int J Sports Med. 2016 Apr;37(4):324-8.

PURPOSE: Our purpose was to verify if the use of the new AquaTrainer® respiratory snorkel lead to an increase of front crawl hydrodynamic drag and whether the constraint of using an adapted turning technique influences its corresponding turning time.

METHODOLOGY: 12 swimmers performed 2 (without and with snorkel) 12×25 front crawl repetitions from low to maximal velocity on the measuring active drag system. Complementarily, 3 swimming turns were compared: open turn with snorkel, tumble turn and open turn without snorkel.

RESULTS: Drag values were similar without vs. with snorkel at 0.9, 1.1, 1.3, 1.5 and 1.7 m.s⁻¹ velocities: 15.84 ± 5.32 vs. 16.18 ± 4.81, 25.60 ± 6.69 vs. 26.03 ± 6.17, 38.37 ± 8.04 vs. 38.88 ± 7.56, 54.64 ± 10.06 vs. 55.08 ± 9.55, 74.77 ± 14.09 vs. 74.92 ± 13.14 N, (respectively, p ≥ 0.05), and high agreement between conditions was observed (p < 0.01). Front crawl swimming with snorkel using the open turn implied an increase in turning time of 14.2 and 5.1% than the tumble turn and open turn without the apparatus (p < 0.01).

CONCLUSIONS: AquaTrainer® snorkel does not lead to an increase in active drag during front crawl performed at a large range of velocities and, consequently, the metabolic energy necessary to overcome total drag will not be affected. However, turning with it requires an additional time that should be taken into account in scientific research and training conditions.

Which are the best VO₂ sampling intervals to characterize low to severe swimming intensities?

de Jesus K, Guidetti L, de Jesus K, Vilas-Boas JP, Baldari C, Fernandes RJ. Int J Sports Med. 2014 Nov;35(12):1030-6.

PURPOSE: Cardiorespiratory response in swimming has been used to better understand aerobic performance, especially by assessing oxygen uptake (VO₂). The current study aimed to compare different VO₂ time-averaging intervals throughout low to severe swimming intensities, hypothesizing that VO₂ values are similar for different time averages at low to moderate and heavy swimming intensities, but not for the severe domain.

METHODOLOGY: 20 male trained swimmers completed an incremental protocol of 7 × 200 m until exhaustion (0.05 m/s increments and 30 s intervals). VO₂ was measured by a portable gas analyser connected to a snorkel system. 6 time average intervals (breath-by-breath, 5, 10, 15, 20 and 30 s) were compared for all the protocol steps.

RESULTS: Breath-by-breath and 5 s average exhibited higher VO₂ values than averages ≥ 10 s for all swimming intensities (P ≤ 0.02; partial η² ≤ 0.28). VO₂ values did not differ between 10, 15, 20 and 30 s averages throughout the incremental protocol (P > 0.05; partial η² ≤ 0.05). Furthermore, 10 and 15 s averages showed the lowest VO₂ mean difference (0.19 mL(·)kg⁻¹·min⁻¹). For the 6 time average intervals analysed, 10 and 15 s averages were those that showed the lowest changes on VO₂ values.

CONCLUSIONS: We recommended the use of 10 and 15 s time averaging intervals to determine relevant respiratory gas exchange parameters along a large spectrum of swimming intensities.

Is the new AquaTrainer® snorkel valid for VO₂ assessment in swimming?

Baldari C, Fernandes RJ, Meucci M, Ribeiro J, Vilas-Boas JP, Guidetti L. Int J Sports Med. 2013 Apr;34(4):336-44.

PURPOSE: The Cosmed AquaTrainer® snorkel, in connection with the K4b2 analyzer, is the most recent instrument used for real time gas analysis during swimming. This study aimed to test if a new AquaTrainer® snorkel with 2 (SV2) or 4 (SV4) valves is comparable to a standard face mask (Mask) being valid for real time gas analysis under controlled laboratory and swimming pool conditions.

METHODOLOGY: 9 swimmers performed 2 swimming and 3 cycling tests at 3 different workloads on separate days. Tests were performed in random order, at constant exercise load with direct turbine temperature measurements, breathing with Mask, SV4 and SV2 while cycling, and with SV2 and SV4 while swimming.

RESULTS: A high agreement was obtained using Passing - Bablok regression analysis in oxygen consumption, carbon dioxide production, tidal volumes, pulmonary ventilation, expiratory fraction of oxygen and carbon dioxide, and heart rate comparing different conditions in swimming and cycling. Proportional and fixed differences were always rejected (95% CI always contained the value 1 for the slope and the 0 for the intercept).

CONCLUSIONS: In conclusion, the new SV2 AquaTrainer® snorkel, can be considered a valid device for gas analysis, being comparable to the Mask and the SV4 in cycling, and to the SV4 in swimming.

Different VO₂max time-averaging intervals in swimming.

Fernandes RJ, de Jesus K, Baldari C, de Jesus K, Sousa AC, Vilas-Boas JP, Guidetti L. Int J Sports Med. 2012 Dec;33(12):1010-5.

PURPOSE: We aimed to determine the effect of sampling interval strategy on VO₂(2max) assessment to establish a standard time averaging method that allows a better identification of the VO₂(2) plateau incidence in swimming.

METHODOLOGY: To this end, 3 incremental protocols utilizing different step lengths for each sampling interval were used to compare VO₂(2max) measurements. 11 trained male swimmers performed 3 repetitions of a front crawl intermittent incremental protocol until exhaustion (increments of 0.05 m.s⁻¹), with 30 s and 24-48 h intervals between steps and tests, respectively) with 200, 300 and 400-m step lengths. VO₂(2) was directly measured, and 6 sampling intervals were compared: bxb and averages of 5, 10, 15, 20 and 30 s.

RESULTS: Shorter sampling intervals (≤ 15 s) allowed the highest incidence of the VO₂(2) plateau, independent of the step lengths used; the 200 and 300-m step protocols accounted for higher percentage of VO₂(2) plateau incidence, and higher VO₂(2max) values, compared to the 400-m step protocol.

CONCLUSIONS: As an optimal sampling interval should be used for the validation of the research findings, and considering that swimmers and coaches prefer less time-consuming protocols, the use of the 10 s time-average interval (once bxb and 5 s samplings present high variability) in a 200-m step incremental protocol for $\dot{V}O_{2\max}$ assessment in swimming is suggested.

Validity of a swimming snorkel for metabolic testing.

Rodríguez FA, Keskinen KL, Kusch M, Hoffmann U. Int J Sports Med. 2008 Feb;29(2):120-8. Epub 2007 Oct 24.

PURPOSE: Two models of a swimming snorkel connected to a portable metabolic cart (Cosmed K4 b2, Rome, Italy) were assessed using a gas exchange simulation system.

METHODOLOGY: Four standardized testing protocols were designed to mimic different swimming conditions and were performed similarly in three conditions so that both snorkels could be compared to measured values obtained by connecting the simulator directly with the gas analyzer.

RESULTS: Simulated and measured values were highly correlated ($R^2 = 0.891$ to 0.998) and in good agreement, with only a small overestimation of expiratory tidal volume (4 %, $p = 0.005$), not large enough to significantly affect the accuracy of ventilation or gas exchange parameters. Values measured using both swimming snorkels also highly correlated with simulated values, particularly for the ventilatory and primary gas exchange variables ($R^2 = 0.996$ and 0.998 in both models for $\dot{V}O_2$ and $\dot{V}CO_2$, respectively). A moderate overestimation of $\dot{F}E_{O_2}$ was observed in both models (2.65 % and 2.48 % relative, $p = 0.03$) and attributed to minimal mixing of inspiratory and expiratory gases, although not affecting $\dot{V}O_2$ measurements.

CONCLUSIONS: We conclude that both snorkels are valid devices for measuring pulmonary breath-by-breath gas exchange parameters in connection with the K4 b2 across a wide physiological range.

Literature Reviews

Portable open-circuit spirometry systems: a review.

Overstreet BS, Bassett DR Jr, Crouter SE, Rider BC, Parr B. J Sports Med Phys Fitness. 2016 Feb 10.

PURPOSE: The purpose of this review is to describe the evolution of portable open-circuit spirometry systems, and discuss their validity, reliability, and principles of operation.

METHODOLOGY: Eleven devices were selected for review: the Oxylog, Aerosport KB1-C, Cosmed K2, Cosmed K4RQ, Cosmed K4b2, MetaMax I, MetaMax II, Metamax3B/VmaxST, Medgraphics VO2000, Oxycon Mobile I and Oxycon Mobile II. The validity (compared to the Douglas bag method (DBM)) and reliability of each device for measuring $\dot{V}O_2$ was summarized.

RESULTS: Mean differences in resting measurements of $\dot{V}O_2$ were within ± 0.05 L·min⁻¹ for all devices except one (difference of 0.17 L·min⁻¹). When compared to the DBM, $\dot{V}O_2$ differences for all devices ranged from 0.01 L·min⁻¹ to 0.29 L·min⁻¹ during submaximal intensity exercise and from 0.01 L·min⁻¹ to 0.36 L·min⁻¹ during vigorous/maximal intensity. During submaximal and maximal intensities, ICC ranged from 0.66-0.99 and CV ranged from 2.0-14.2%. Of these devices, four used breath-by-breath technology and six used micro-proportional sampling technology. Validity and reliability of devices did not seem to differ between methods of gas collection.

CONCLUSIONS: Of the three commercially available devices in 2015, all were found to be reliable. Two of the three systems (Cosmed K4b2 and Oxycon Mobile II) provided valid estimates of $\dot{V}O_2$ (mean values within ± 0.10 L/min-1 of DBM) during rest, and submaximal and maximal intensities, while the MetaMax3B slightly overestimated $\dot{V}O_2$, particularly at maximal exercise.