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Letter to editor

Comparison of metabolic gas analysis between a standard laboratory system and a portable device

Dear Editor-in-Chief

The recent development of portable metabolic gas analysis systems gives scientists the capability of measuring physiological data, including oxygen consumption, associated with multi-directional movements in the field. However, careful consideration is necessary when comparing data from two metabolic systems (Jakovljevic et al., 2008), such as a portable metabolic system and a laboratory metabolic cart. Our group was specifically interested in comparing gas analysis data obtained using a portable metabolic system, the K4b^2 (COSMED srl, Rome, Italy), and the laboratory metabolic cart, the TrueOne® 2400 (Parvo Medics, Salt Lake City, UT). Although the readings from the K4b^2 were similar to those from the Douglas-bag method during exercise (McLaughlin et al., 2000), Duffield et al. (2004) found that the K4b^2 did not compare well to a standard laboratory metabolic cart. Furthermore, values measured by the K4b^2 have not been directly compared to those measured by the TrueOne 2400 (T2400), which also gives readings similar to those from the Douglas-bag method (Bassett et al., 2001; Crouter et al., 2006). The purpose of this investigation was to assess the agreement between measurements of A) relative oxygen consumption (VO_2), B) respiratory exchange ratio (RER), and C) minute ventilation (V_E), obtained from the K4b^2 and the T2400 during level treadmill exercise.

Ten experienced runners (6M: 30.2 ± 2.8 years, 1.83 ± 0.05 m, 81.8 ± 7.1 kg; 4F: 27.8 ± 2.4 years, 1.66 ± 0.03 m, 57.7 ± 4.4 kg; mean ± SD) completed the study. Each subject walked and ran on a standard laboratory treadmill while metabolic gases were measured using either the T2400 or the K4b^2 in a balanced-random order. Test sessions were separated by at least 48 hours and were completed within a 12-day period (5.3 ± 4.2 days) to minimize the potential effects of fatigue and altered fitness level, respectively.

After donning a heart rate monitor (Polar Electro Oy, Model 6029, Kempele, Finland) and metabolic equipment, subjects began the testing protocol with a five-minute standing baseline period. Once the baseline period was completed, subjects walked on a level treadmill at 0.89 m·s^{-1} for the first three-minute stage. Speed was increased 0.45 m·s^{-1} every three minutes until the subject's heart rate reached 85% of a previously measured peak heart rate (if measured within one year) or an age-predicted maximum heart rate (220 beats·min^{-1} - age). All ten subjects completed speeds up to 2.24 m·s^{-1}, nine subjects completed the 2.68 m·s^{-1} speed, and six subjects completed the 3.13 m·s^{-1} speed. VO_2, RER, and V_E from the last minute of each stage were averaged and used for subsequent analysis.

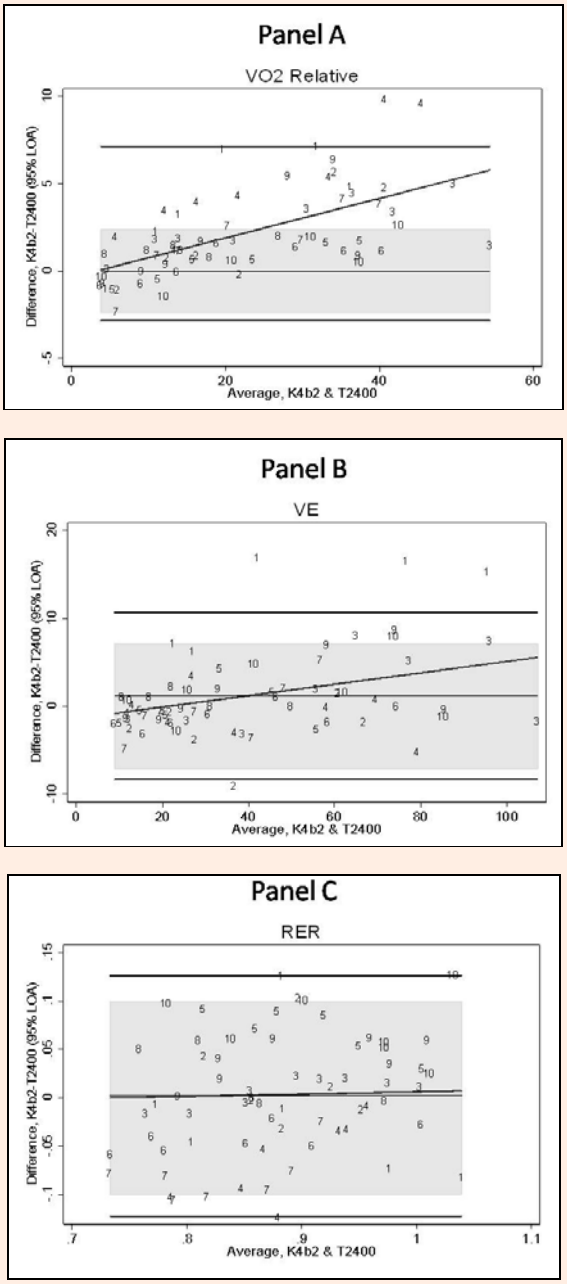

Figure 1. Repeated observations of VO_2 (Panel A), V_E (Panel B), and RER (Panel C) measured by the metabolic systems K4b^2 and T2400 at different speeds. The plotted upper and lower horizontal lines are the Bland-Altman plots of limits of agreement (LOA). Shaded regions indicate ideal modeled LOA for repeated observations using only the T2400 device.

Bland-Altman plots (see Figure 1) show values of the difference [K4b^2 – T2400] versus the average [(K4b^2 + T2400)/2] for each test point, with data pertaining to

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each subject represented as a number (1-10), as well as a repeated-measures regression line (Bland and Altman, 2007). These plots also include the 95% limits of agreement (LOA) for the differences between measurements by the two devices. For comparison purposes, the shaded areas indicate what the approximate 95% LOA would be if each subject had repeated the test twice on the T2400 at each speed, which we called idealized limits of agreement (ILOA). To calculate these ILOA, a mixed-effects regression model (Goldstein, 1995) was fitted to estimate the mean response, as well as components of between- and within-subject variance for each device as a function of speed for each of the metabolic variables. The ILOA then were calculated as $\pm 1.96\sigma\sqrt{2}$, where σ is the within-subject standard deviation of repeated T2400 measurements. Stata Statistical Software (StataCorp, 2007) was used for all data analyses.

The measured relative VO_2 was similar for the two devices at rest (difference values lie between ILOA when relative VO_2 is low; see Panel A). However, as exercise intensity increased (positive slope of regression line), the $K4b^2$ measurements increased relative to the T2400 measurements. The overall bias is indicated by the failure of the LOA to be centered at zero. A similar but not as severe pattern for V_E is indicated in Panel B, where although the slope is positive ($p < 0.001$), it is fairly small in magnitude. In addition, although the overall bias was smaller for V_E than for relative VO_2 (the LOA were more closely centered at zero), the effect was not as strong (the slope was less severe; therefore, fewer values were outside the idealized LOA). Panel C shows good agreement between devices for RER considering the range of RER measurements made by either device.

The main findings were that the $K4b^2$ did not duplicate T2400 VO_2 or V_E measurements well, especially at higher levels of exercise. The $K4b^2$ agreed better with the T2400 when measuring V_E, but a bias exists that increases with exercise intensity (speed). The $K4b^2$ seemed to give RER results similar to those of the T2400. In view of these results, we do not recommend comparing relative VO_2 and V_E between the $K4b^2$ and the T2400 during exercise. However, although it appears that the $K4b^2$ and the T2400 are not directly comparable, the $K4b^2$ allows metabolic measurements to be made during field tasks, which may not be possible when traditional metabolic gas analysis systems such as the T2400 are used. In this case, because the $K4b^2$ has been shown to give consistent readings (Duffield et al., 2004), $K4b^2$ measurements should be compared only with other $K4b^2$ measurements.

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