Assessment of the Aerosport TEEM 100 Portable Metabolic Measurement System

By: Laurie Wideman, Nancy M. Stroudemire, Kimberly A. Pass, Christina L. McGinnes, Glenn A. Gaesser, and Arthur Weltman

Wideman, L., Stoudemire, N., Pass, K.A., McGinnes, C.L., Gaesser, G.A., and Weltman, A. 1996. Assessment of the Aerosport TEEM 100 portable metabolic measurement system. *Medicine & Science in Sport & Exercise* 28(4): 509-515.

Abstract:

The present study evaluated the utility of a portable metabolic measurement system, the Aerosport TEEM 100. A total of 505 data points [242 from incremental (INC) and 263 from constant load (CL) exercise] were collected on 12 subjects (age = 25 ± 4 yr), by placing the Aerosport TEEM 100 medium flow pneumotach and mouthpiece in-line with a validated system, the Rayfield system. When $\cdot VO_2$ values were separated into categories (<1.5, 1.5-2.0, 2.0-2.5, 2.5-3.0, >3.0 $l \cdot min^{-1}$), there was a small but statistically significant difference between the two metabolic measurement systems for $\cdot VO_2$, $\cdot VCO_2$, $\cdot V_E$, RER,$\%_E CO_2$, and$\%_E O_2$ during both INC and CL exercise and measurement error for $\cdot VO_2$ ranged between 2% and 11%. Correlations for $\cdot VO_2$ values during INC and CL exercise between the two systems were r = 0.95 (SE_{est} ± 0.18 $l \cdot min^{-1}$) and r = 0.96 (SE_{est} ± 0.29 $l \cdot min^{-1}$), respectively. Correlations for RER were r = 0.82 (SE_{est} ± 0.08) and r = 0.47(SE_{est} ± 0.11), for INC and CL, respectively. Results from the present investigation indicate that the Aerosport TEEM 100 has utility for the assessment of $\cdot VO_2$, but the estimation of carbohydrate and fat utilization from RER should be used with caution.
Key Words: OXYGEN UPTAKE; EXERCISE; METABOLISM; GAS EXCHANGE; VENTILATION

Article:

The use of indirect calorimetry to measure oxygen uptake is an integral part of research and clinical assessment in the areas of exercise physiology and the sport sciences. For the most part, the measurement of oxygen uptake has been restricted to the laboratory or clinical setting due to cumbersome equipment. Several attempts (1,2,4) have been made to validate portable systems that are currently on the market, but each system has limitations. A truly portable and valid system would greatly facilitate research in areas where activities can not be performed in the laboratory.

Recently, the Aerosport TEEM 100 Total Metabolic Analysis System(Aerosport, Inc., Ann Arbor, MI) was developed for use in laboratory and nonlaboratory settings. This device measures 25.4 × 25.4 × 8.9 cm, weighs a total of 3.3 kg and operates on both AC/DC and battery power. The purpose of the present study was to compare metabolic measures collected with the portable Aerosport TEEM 100 system with a validated metabolic system(Rayfield).

METHODS

Metabolic Measures

Validated technique: Rayfield Metabolic Measurement System. Metabolic data were collected using standard open circuit spirometric techniques. Inspired ventilation was measured using a previously calibrated dry gas meter (Rayfield RAM-9200) fitted with a potentiometer. Output from the potentiometer was continuously integrated into an Apple IIe computer (Rayfield REP200). Expired ventilation ($\cdot V_E$) was channeled from a Hans Rudolph high-velocity valve through low-resistance plastic tubing into a 7-l mixing chamber. The concentrations of expired oxygen and carbon dioxide($\%_E O_2$,$\%_E CO_2$) in the mixing chamber were continuously sampled by an Applied Electrochemistry S-3A oxygen analyzer and a Beckman LB-2 carbon dioxide analyzer, respectively. Outputs from the gas analyzers were continuously integrated into the Apple IIe computer (Rayfield REP200). This system has been validated in our laboratory using a 120-l Tissot gasometer for volume measures and the micro-Scholander technique for measures of expired CO_2 and O_2. For ventilation, the relationship between the Rayfield Ram 9200 gas meter and Tissot spirometer (48 paired observations between 0-100 1) was Vol Tissot = 1.0207 (Vol Rayfield) - 0.0517 1, r = 0.99985. The relationship was programmed into the Rayfield REP 200 software. The linearity of the gas analyzers in the physiological range has been verified with several gases (Micro Scholander technique) with$\%O_2$ ranging from 14% to 21% and$\%CO_2$ ranging from 0% to 6%.

Portable technique: Aerosport TEEM 100. The Aerosport TEEM 100 system is also based on open circuit spirometic techniques. As respiratory gas is exhaled through the pneumotach, a microsample proportional to the expired flow is drawn into the unit. Proportional sampling means that for each defined unit of volume that passes through the pneumotach, a microsample of flow, proportional to the total flow, is admitted to the unit via a high-frequency sampling valve. A fixed rate of the proportional sample, known as a pulse, is drawn into a micromixing chamber (10 cc). For each pulse drawn in, a pulse of identical volume from the mixing system is emitted to the oxygen and carbon dioxide detectors. Over a fixed time period, electronic variable sampling, or EVS, allows the pulse trains to be reduced to a constant volume, resulting in similar equilibration times at varying expired flow rates. After gas analysis and flow integration, the gas is exported out the back of the system to ambient air. The whole system is under microprocessor control. Respiratory exchange ratio (RER), volume of oxygen consumed ($\cdot VO_2$), and volume of CO_2 produced ($\cdot VCO_2$) are calculated using standard procedures (3).

The oxygen sensor is a galvanic fuel cell. When there is no oxygen, there is no current and no output. The output is essentially linear with a line of identity drawn through zero and 20.93% O_2. Carbon dioxide is measured using nondispersive infrared (NDIR) analysis. Ambient air is used to zero the sensor and also is used to establish a baseline to which the response of the detector is referenced. CO_2 within the detector's path changes the output as defined by Beer's Law (3). Expired volume is measured using a flat plate orifice pneumotach. The orifice is constructed to produce a maximal pressure drop of 4 inches of water at peak flow. A silicon wafer, bonded string, gauge pressure transducer connected across the orifice measures the differential pressure. In the present study, all data were collected using the medium flow pneumotach.

Data for $\cdot V_E$,$\%_E CO_2$,$\%_E O_2$, RER,$\cdot VCO_2$, and $\cdot VO_2$ were collected simultaneously with both systems by placing the Aerosport TEEM 100 mouthpiece and pneumotach in line with the Hans Rudolph valve used with the Rayfield system.

Subjects

All subjects (N = 12, mean age = 25 ± 4 yr, height = 169.9± 9.5 cm, weight = 66.8 ± 10.2 kg) provided written informed consent for participation in the studies, which were approved by the University of Virginia Institutional Review Board.

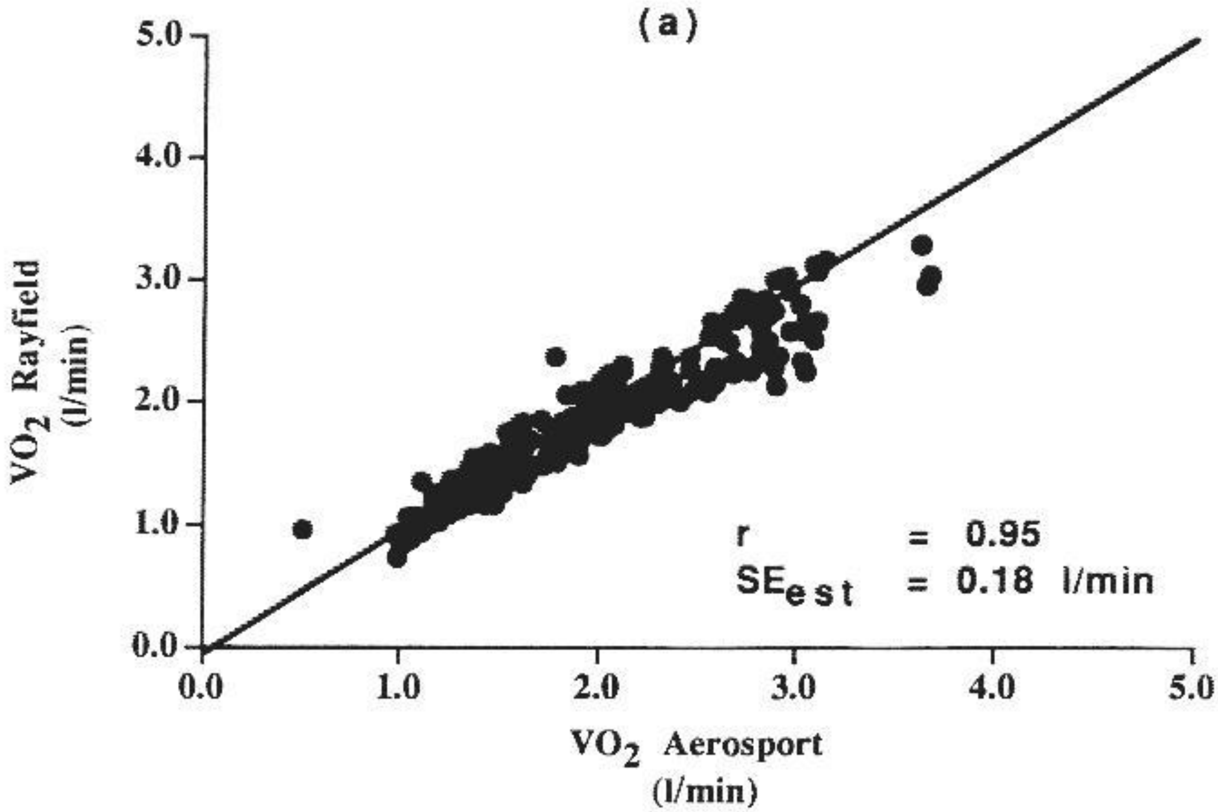
Ventilation and gas exchange were monitored minute-by-minute using both devices during two types of protocols; incremental exercise (INC) and constant load (CL) exercise. The incremental exercise protocols included running and stepping protocols. The running protocol was a horizontal treadmill protocol which began at 110 $m \cdot min^{-1}$ and increased 10 $m \cdot min^{-1}$ every 3 min. The incremental step protocol was performed on an 8-inch step at an initial stepping cadence of 15 $steps \cdot min^{-1}$. Step rate increased every 3 min by 2.5 $steps \cdot min^{-1}$ until volitional exhaustion. Three separate continuous exercise protocols consisted of running for 30 min at the velocity corresponding to the following intensities: 1) 60% heart rate (HR) max, 2) 90% HR max, and 3) blood lactate concentration of 4.0 mM. These protocols were chosen to evaluate the Aerosport TEEM 100 because they were part of separate ongoing experiments in our laboratory. Not all subjects completed all protocols.

Statistical Analysis

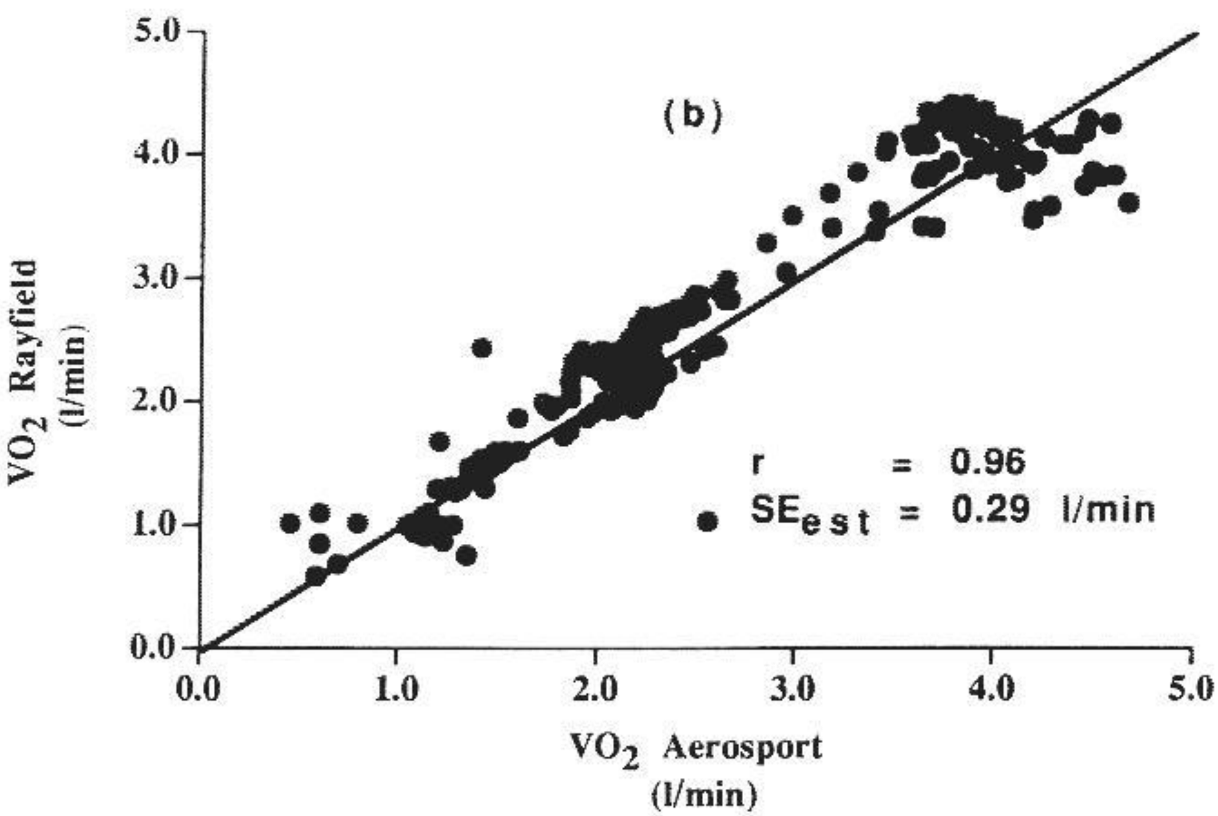
Data were initially analyzed separately for incremental and constant load exercise, then combined and reanalyzed. Regression analysis was utilized to examine the relationship between the Aerosport and Rayfield systems for each of the metabolic measures. The mean difference between the two systems for each metabolic measure was analyzed using paired Student's t-tests. Standard error of estimate (SE_{est}) was calculated using the following formula: $SE_{est} = SD_y (1 - rxy^2)^{1/2}$, where rxy^2 is the validity coefficient and SD_y is the standard deviation of the Rayfield score. Statistical significance was set at$P < 0.05$.

RESULTS

Figure 1 shows the relationship between$\cdot VO_2$ measured with the Rayfield system (y-axis) and $\cdot VO_2$ measured with the Aerosport TEEM 100 system (x-axis) for INC exercise (1a) and CL exercise (1b). The lines of identity are shown and SE_{est} were± 0.18 $l \cdot min^{-1}$ (INC) and ± 0.29 $l \cdot min^{-1}$ (CL). Correlations between metabolic systems for the$\cdot VO_2$ data were r = 0.95 (INC) and r = 0.96 (CL). When all data were combined into a single data set (N = 505 observations), no significant differences were observed between the metabolic systems (mean$\cdot VO_2$ = 2.22 ± 0.89 $l \cdot min^{-1}$ for Aerosport; mean$\cdot VO_2$ = 2.10 ± $l \cdot min^{-1}$ for Rayfield). Regression analysis revealed a slope of 1.00 and an intercept of -0.01 $l \cdot min^{-1}$ (r = 0.95).



(a)
5.0
4.0
3.0
2.0
1.0
0.0
VO2 Rayfield
(l/min)
r = 0.95
SEest = 0.18 l/min
0.0
1.0
2.0
3.0
4.0
5.0
VO2 Aerosport
(l/min)



(b)
5.0
4.0
3.0
2.0
1.0
0.0
VO2 Rayfield
(l/min)
r = 0.96
SEest = 0.29 l/min
0.0
1.0
2.0
3.0
4.0
5.0
VO2 Aerosport
(l/min)

Figure 1-The relationship between ·VO2 measured using the Rayfield and the Aerosport TEEM 100 during incremental exercise (a) and constant load exercise (b).

To further evaluate differences between the two systems, the data were separated into INC and CL protocols and divided into categories based on absolute $\cdot VO_2$ as measured by the Rayfield system. The results for INC exercise are presented in Table 1, results for CL exercise are presented in Table 2 and combined results are presented in Table 3. Small but statistically significant mean differences were observed between the two metabolic measurement systems in each of the $\cdot VO_2$ categories, for INC, CL, and combined data sets. Although the absolute differences between the Rayfield and Aerosport TEEM 100 were similar for the two types of protocols, the data showed directional changes. This point is demonstrated by observing the measurement error for $\cdot VO_2$ when the data are combined (Table 3). In the lowest category ($\cdot VO_2 < 1.5\ l\cdot min^{-1}$), the majority of data points were INC exercise, and the overestimation of 8% mirrors the error in the INC exercise. At$\cdot VO_2$ values of $> 3.0\ l\cdot min^{-1}$, nearly all the data points were from CL exercise, consequently, the combined and CL measurement of error for $\cdot VO_2$ was identical (underestimation of 3%). At$\cdot VO_2$ values between 1.5 and 3.0 $l\cdot min^{-1}$, the error of measurement for $\cdot VO_2$ during INC and CL were nearly equal in magnitude, but opposite in direction. Therefore, when the data were combined, the overall error of measurement of $\cdot VO_2$ was less than when the protocols were separated.

	Rayfield	Aerosport	% of Rayfield
$\dot{V}O_2$ (0.5–1.5 l · min^{-1}) (N = 45)			
$\dot{V}O_2$ (l · min^{-1})	1.19 ± 0.25	1.23 ± 0.33	103
$\dot{V}CO_2$ (l · min^{-1})	1.19 ± 0.25	1.10 ± 0.29*	92
RER	0.85 ± 0.09	0.91 ± 0.13*	107
$\dot{V}O_2$ (1.5–2.0 l · min^{-1}) (N = 31)			
$\dot{V}O_2$ (l · min^{-1})	1.69 ± 0.19	1.65 ± 0.25	98
$\dot{V}CO_2$ (l · min^{-1})	1.46 ± 0.33	1.43 ± 0.32*	98
RER	0.85 ± 0.12	0.86 ± 0.09	101
$\dot{V}O_2$ (2.0–2.5 l · min^{-1}) (N = 72)			
$\dot{V}O_2$ (l · min^{-1})	2.28 ± 0.15	2.16 ± 0.18*	95
$\dot{V}CO_2$ (l · min^{-1})	2.10 ± 0.19	2.05 ± 0.20*	98
RER	0.92 ± 0.08	0.95 ± 0.10*	103
$\dot{V}O_2$ (2.5–3.0 l · min^{-1}) (N = 38)			
$\dot{V}O_2$ (l · min^{-1})	2.70 ± 0.12	2.40 ± 0.12*	89
$\dot{V}CO_2$ (l · min^{-1})	2.49 ± 0.26	2.18 ± 0.18*	88
RER	0.92 ± 0.08	0.91 ± 0.06	99
$\dot{V}O_2$ (>3.0 l · min^{-1}) (N = 77)			
$\dot{V}O_2$ (l · min^{-1})	3.99 ± 0.31	3.88 ± 0.38*	97
$\dot{V}CO_2$ (l · min^{-1})	4.14 ± 0.56	3.56 ± 0.34*	86
RER	1.04 ± 0.15	0.93 ± 0.08*	89

* $P < 0.05$.

TABLE 1. Mean ± SD for metabolic variables categorized by absolute·VO_2 obtained with the Rayfield system during incremental protocols(N = 242).

	Rayfield	Aerosport	% of Rayfield
$\dot{V}O_2$ (0.5–1.5 $l \cdot min^{-1}$) (N = 45)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	1.19 ± 0.25	1.23 ± 0.33	103
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	1.19 ± 0.25	1.10 ± 0.29*	92
RER	0.85 ± 0.09	0.91 ± 0.13*	107
$\dot{V}O_2$ (1.5–2.0 $l \cdot min^{-1}$) (N = 31)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	1.69 ± 0.19	1.65 ± 0.25	98
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	1.46 ± 0.33	1.43 ± 0.32*	98
RER	0.85 ± 0.12	0.86 ± 0.09	101
$\dot{V}O_2$ (2.0–2.5 $l \cdot min^{-1}$) (N = 72)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	2.28 ± 0.15	2.16 ± 0.18*	95
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	2.10 ± 0.19	2.05 ± 0.20*	98
RER	0.92 ± 0.08	0.95 ± 0.10*	103
$\dot{V}O_2$ (2.5–3.0 $l \cdot min^{-1}$) (N = 38)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	2.70 ± 0.12	2.40 ± 0.12*	89
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	2.49 ± 0.26	2.18 ± 0.18*	88
RER	0.92 ± 0.08	0.91 ± 0.06	99
$\dot{V}O_2$ (>3.0 $l \cdot min^{-1}$) (N = 77)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	3.99 ± 0.31	3.88 ± 0.38*	97
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	4.14 ± 0.56	3.56 ± 0.34*	86
RER	1.04 ± 0.15	0.93 ± 0.08*	89

* $P < 0.05$.

TABLE 2. Mean ± SD for metabolic variables categorized by absolute·VO_2 obtained with the Rayfield system during constant load protocols (N = 263).

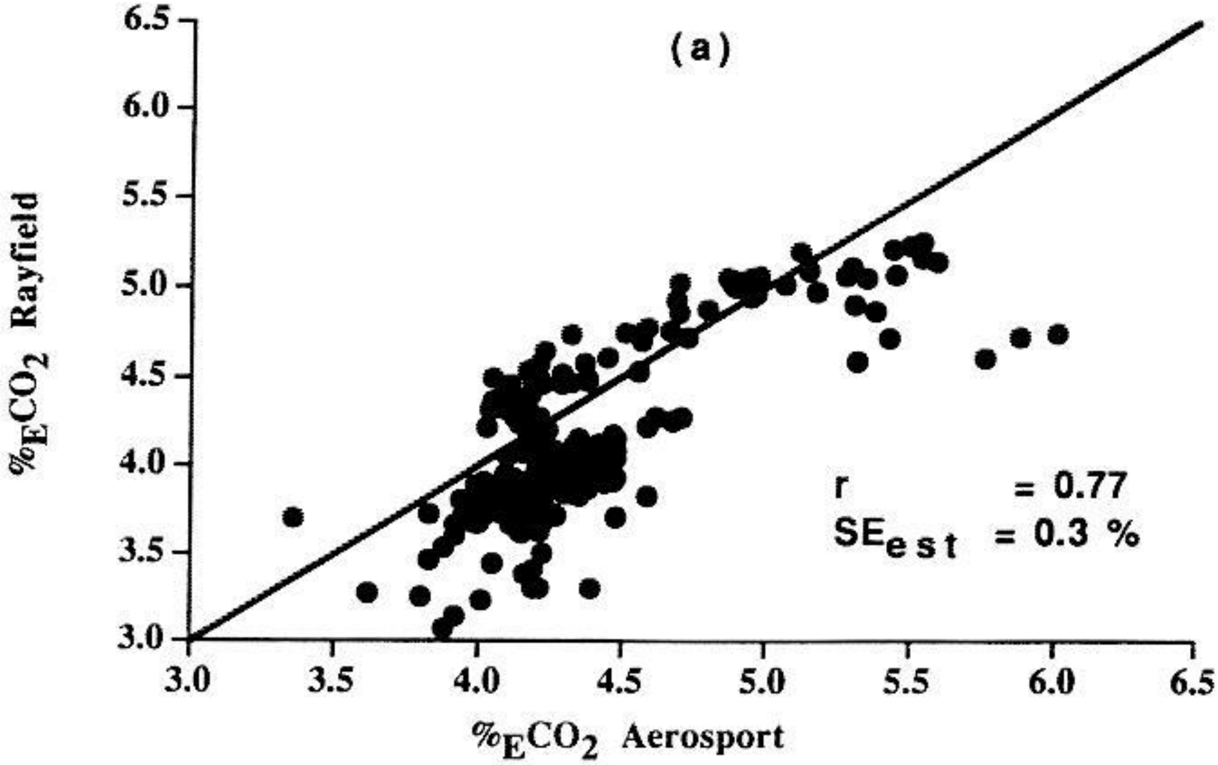
	Rayfield	Aerosport	% of Rayfield
$\dot{V}O_2$ (0.5–1.5 $l \cdot min^{-1}$) (N = 139)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	1.20 ± 0.21	1.30 ± 0.26*	108
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	1.08 ± 0.28	1.21 ± 0.26*	112
RER	0.87 ± 0.11	0.94 ± 0.11*	108
$\dot{V}O_2$ (1.5–2.0 $l \cdot min^{-1}$) (N = 100)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	1.75 ± 0.16	1.81 ± 0.25*	103
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	1.63 ± 0.31	1.70 ± 0.32*	104
RER	0.92 ± 0.13	0.94 ± 0.10	102
$\dot{V}O_2$ (2.0–2.5 $l \cdot min^{-1}$) (N = 118)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	2.27 ± 0.14	2.29 ± 0.29	101
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	2.16 ± 0.31	2.18 ± 0.36	101
RER	0.95 ± 0.13	0.96 ± 0.09	101
$\dot{V}O_2$ (2.5–3.0 $l \cdot min^{-1}$) (N = 65)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	2.71 ± 0.12	2.59 ± 0.28*	96
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	2.45 ± 0.31	2.32 ± 0.34*	95
RER	0.90 ± 0.11	0.90 ± 0.07	100
$\dot{V}O_2$ (>3.0 $l \cdot min^{-1}$) (N = 83)			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	3.93 ± 0.37	3.83 ± 0.40*	97
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	4.04 ± 0.66	3.56 ± 0.40*	88
RER	1.03 ± 0.16	0.93 ± 0.08*	90

* $P < 0.05$.

TABLE 3. Mean ± SD for metabolic variables categorized by absolute·VO_2 obtained as measured with the Rayfield system. Data from both incremental and constant load protocols were pooled for the analysis(N = 505).

Because there were only seven observations in the highest ·VO_2 category (>3.0 $l \cdot min^{-1}$) with INC exercise, these data were not included in Table 1. In each of the other·VO_2 categories during INC exercise, the Aerosport TEEM 100 produced higher values for all variables except$\%_EO_2$ (not shown). At the lowest ·VO_2 during CL exercise (Table 2), the Aerosport TEEM 100 produced a higher ·VO_2 value than Rayfield. At higher metabolic rates, the Aerosport TEEM 100 produced lower·VO_2 values than Rayfield. At the lowest ·VO_2, the Aerosport TEEM 100 produced higher values in all the metabolic variables except ·VCO_2. For ·VO_2 between 1.5 and 2.5 $l \cdot min^{-1}$, the Aerosport TEEM 100 and Rayfield systems gave similar values for all variables and the error observed in $\cdot VO_2$ was due exclusively to error in $\cdot V_E$. At $\cdot VO_2 > 2.5$ l·min^{-1}, the Aerosport TEEM 100 produced lower values for all variables except$\%_E O_2$.

To assess the contribution of differences in$\%_E CO_2$ for the determination of $\cdot VO_2$, a calculation of $\cdot VO_2$ was completed without using measured$\%_E CO_2$. In both INC and CL exercise, the $\cdot VO_2$ changed by less than 2%. While the correlations between metabolic systems for$\%_E CO_2$ were acceptable for both INC and CL exercise ($r = 0.77$ and 0.94, respectively) (Fig. 2), the range of error in the measurement of$\%_E CO_2$ was 2%-10%. However, the contribution of error in measurement of$\%_E CO_2$ to the error in measurement of $\cdot VO_2$ was minimal. It should be noted that there was a systematic overestimation in the$\%_E CO_2$ measured during INC exercise and during CL exercise at $\cdot VO_2$ values < 1.5 l·min^{-1} (range 3%-9%). At $\cdot VO_2 > 2.5$ l·min^{-1} during CL exercise, there was a systematic underestimation of$\%_E CO_2$ (6% and 10%).


(a)
r = 0.77
SEest = 0.3 %
%ECO2 Rayfield
%ECO2 Aerosport
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5

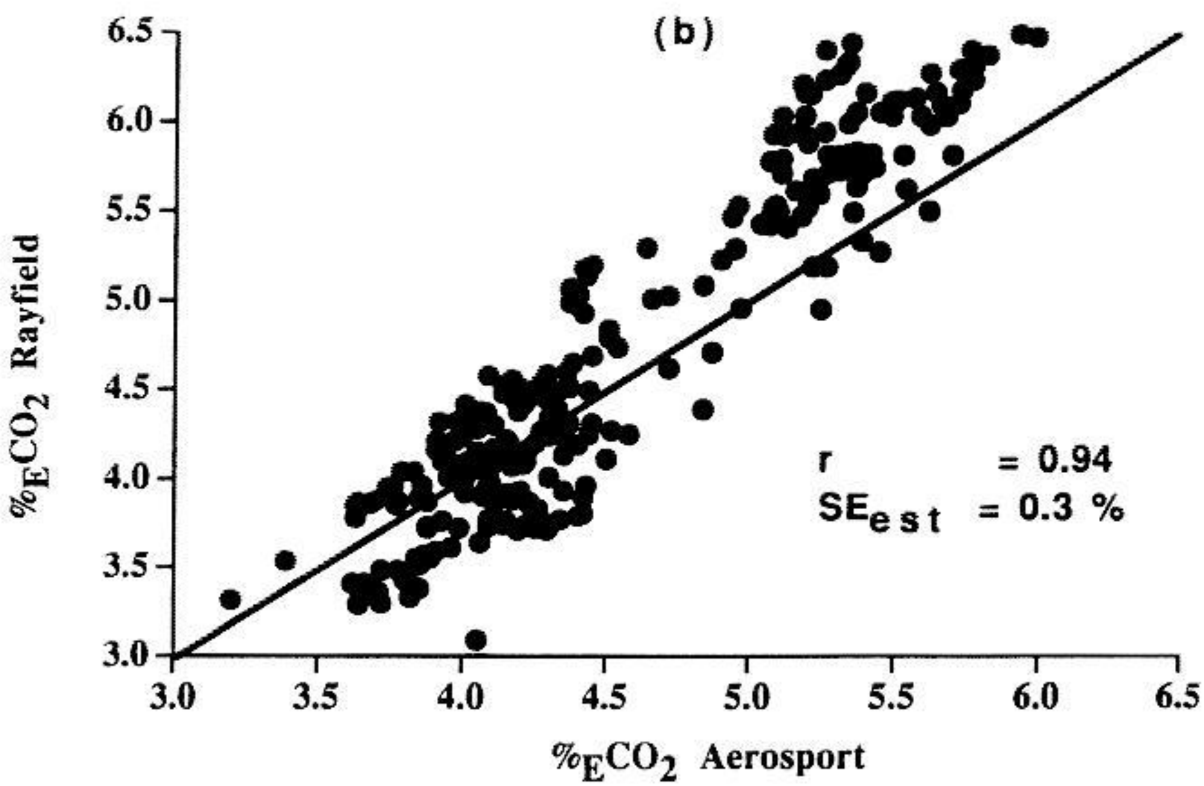

(b)
r = 0.94
SEest = 0.3 %
%ECO2 Rayfield
%ECO2 Aerosport
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5

Figure 2-The relationship between the%ECO2 measured with the Rayfield and the Aerosport TEEM 100 during incremental (a) and constant load (b) exercise.

There were also large discrepancies in the $\cdot VCO_2$ values for these categories. In all cases during INC exercise, $\cdot VCO_2$ values were overestimated by the Aerosport TEEM 100 (range 5%-17%). In all$\cdot VO_2$ categories during CL exercise, $\cdot VCO_2$ was underestimated (range 2%-14%). Figure 3 shows the relationship for $\cdot VCO_2$ during INC (Fig. 3a) and CL (Fig. 3b) exercise. The SE_{est} for$\cdot VCO_2$ were ± 0.15 and 0.24 $l \cdot min^{-1}$ (INC and CL. respectively) and the correlations between metabolic systems were r = 0.97(INC) and r = 0.98 (CL). While correlations for values were high, the large systematic bias in certain $\cdot VO_2$ categories is problematic and contributes to the poor correlations for RER values during both INC and CL exercise (Fig. 4). The correlation between the metabolic measurement systems for the RER data during INC exercise (Fig. 4a) was r = 0.82, with a SE_{est} of ± 0.08. During CL (Fig. 4b), the correlation for the RER measured with the two metabolic systems was considerably lower (r = 0.47, SE_{est} = 0.11), than during INC. If the lowest and highest$\cdot VO_2$ categories were eliminated and the data were pooled for the$\cdot VO_2$ range where RER values were similar between the two systems(N = 290), the r = 0.79 with a SE_{est} of ± 0.17.

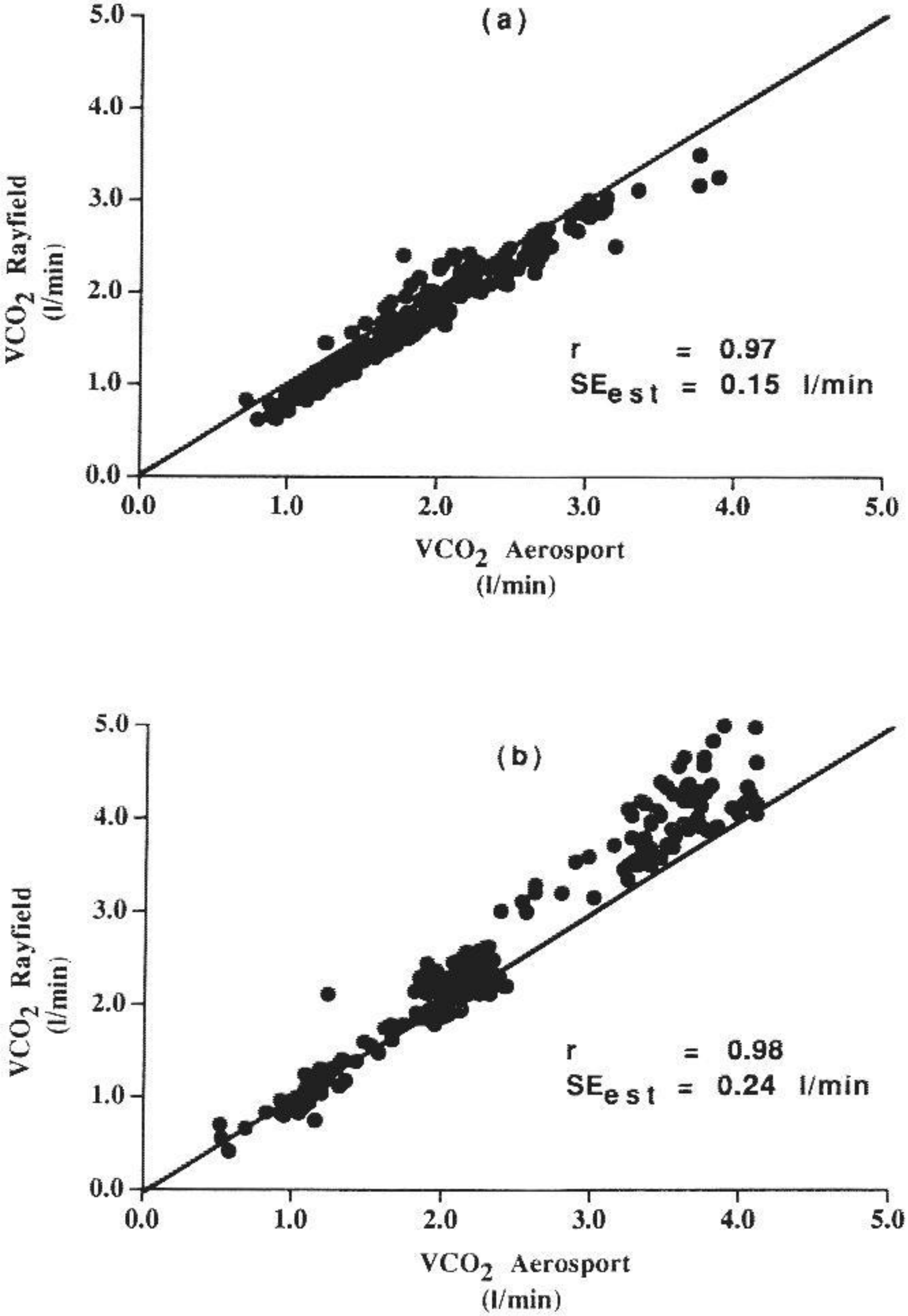
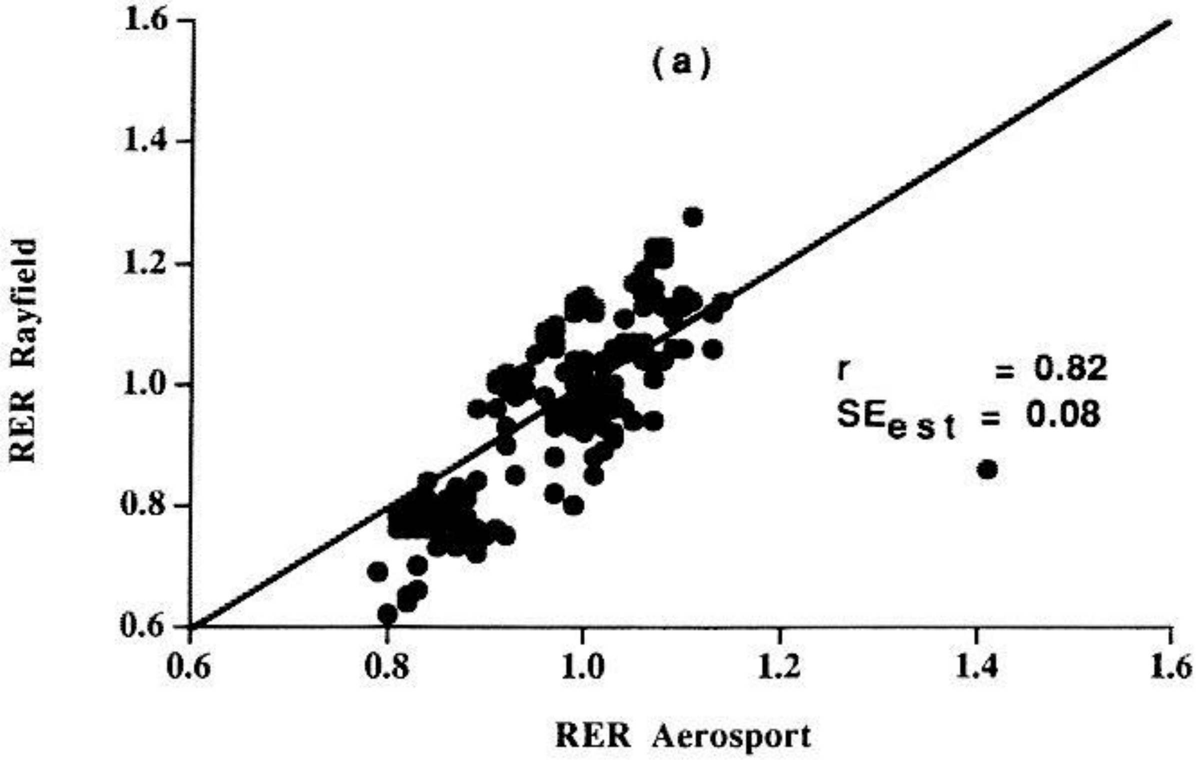

(a)
5.0
4.0
3.0
2.0
1.0
0.0
VCO2 Rayfield
(l/min)
r = 0.97
SEest = 0.15 l/min
0.0
1.0
2.0
3.0
4.0
5.0
VCO2 Aerosport
(l/min)
(b)
5.0
4.0
3.0
2.0
1.0
0.0
VCO2 Rayfield
(l/min)
r = 0.98
SEest = 0.24 l/min
0.0
1.0
2.0
3.0
4.0
5.0
VCO2 Aerosport
(l/min)

Figure 3-The relationship between $\cdot VCO_2$ measured with the Rayfield and the Aerosport TEEM 100 during incremental (a) and constant load(b) exercise.


1.6
1.4
1.2
1.0
0.8
0.6
(a)
RER Rayfield
r = 0.82
SE_{est} = 0.08
0.6
0.8
1.0
1.2
1.4
1.6
RER Aerosport

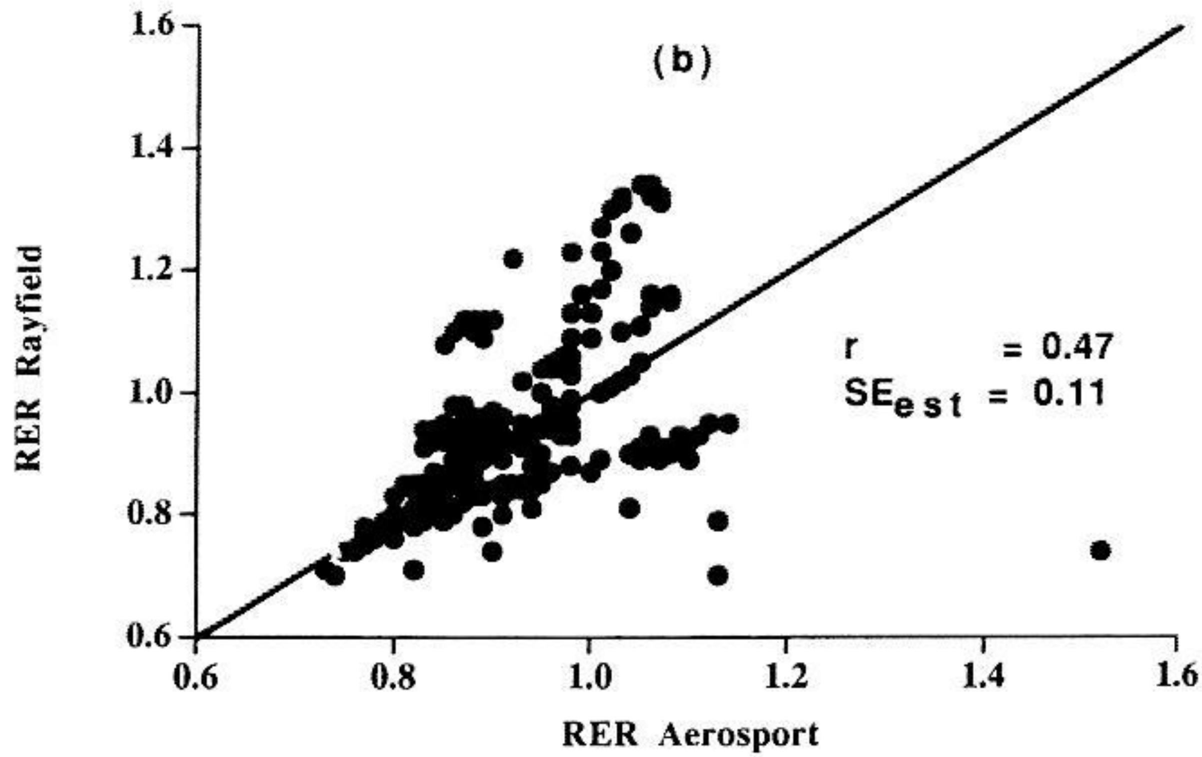
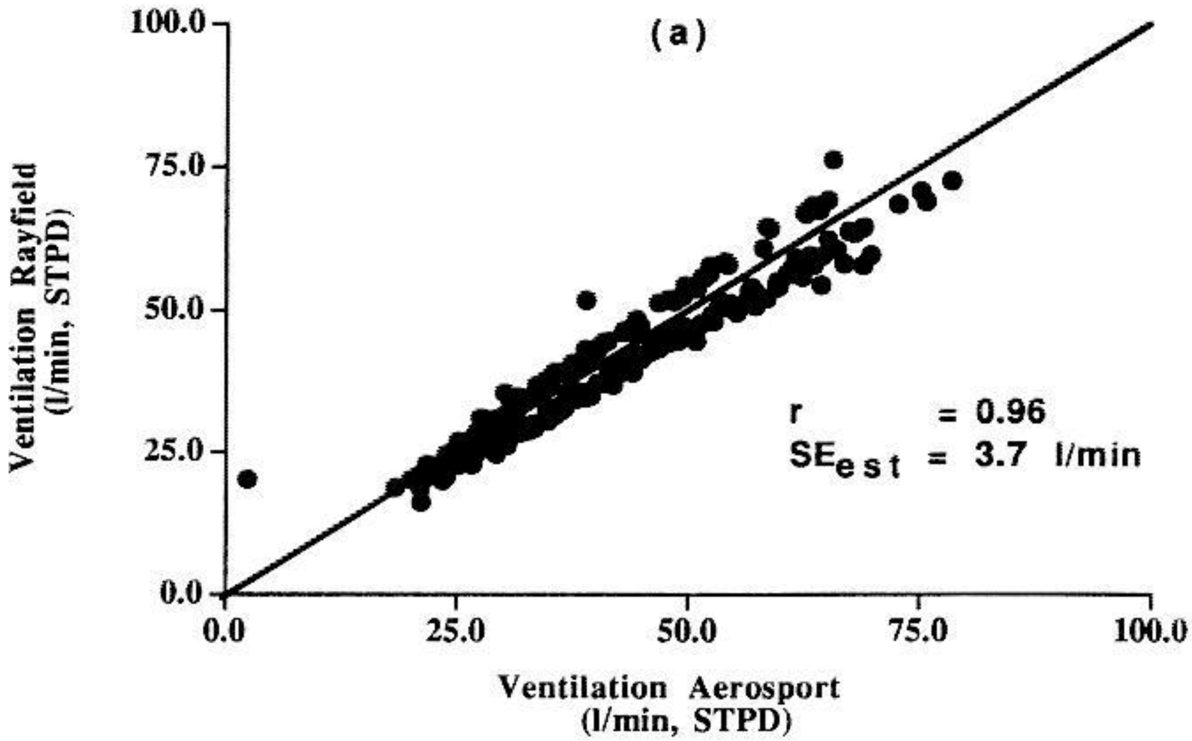
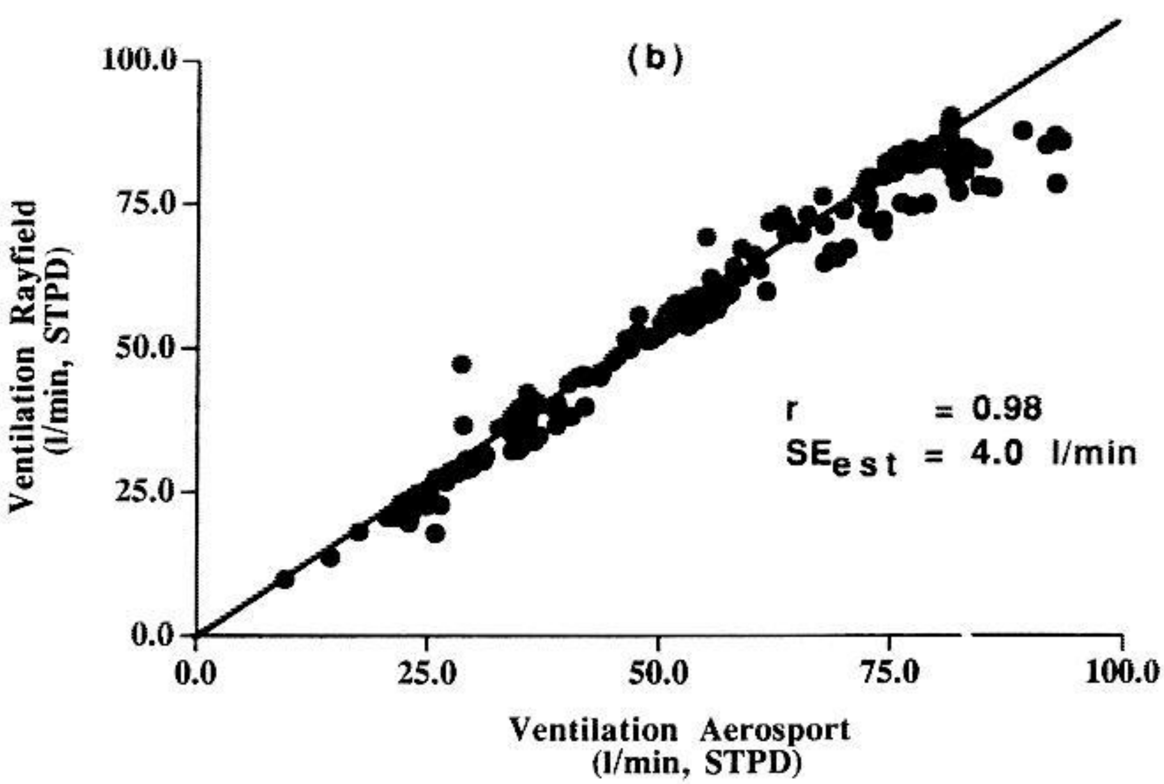

1.6
1.4
1.2
1.0
0.8
0.6
(b)
RER Rayfield
r = 0.47
SE_{est} = 0.11
0.6
0.8
1.0
1.2
1.4
1.6
RER Aerosport

Figure 4-The relationship between RER measured with the Rayfield and the Aerosport TEEM 100 during incremental (a) and constant load (b) exercise.

Figure 5 shows the relationship between the Rayfield system and the Aerosport TEEM 100 system for ventilation, during INC exercise(a) and CL exercise (b). Standard errors of estimate for $\cdot V_E$ were 3.7 and 4.0 $l \cdot min^{-1}$ (INC and CL, respectively) and correlations between the metabolic systems were $r = 0.96$ (INC) and $r = 0.98$ (CL). During INC exercise (Table 1), the largest errors observed for $\cdot VO_2$ were due to differences in $\cdot V_E$, since values for $\%_E O_2$ were nearly identical. At $\cdot VO_2 < 1.5$ $l \cdot min^{-1}$ and at $\cdot VO_2$ between 2.0 and 2.5 $l \cdot min^{-1}$, 75% and 50% of the error respectively, was due to $\cdot V_E$. During CL exercise at a $\cdot VO_2$ between 2.5 and 3.0 $l \cdot min^{-1}$, 64% of the error in $\cdot VO_2$ was accounted for by differences in $\cdot V_E$. The contribution of error for $\cdot V_E$ was calculated by substituting the Rayfield $\cdot V_E$ for the Aerosport TEEM 100 $\cdot V_E$, when $\cdot VO_2$ was calculated for the Aerosport TEEM 100. The percentage change in error was determined by comparing the error in $\cdot VO_2$ using $\cdot V_E$ from the two systems.



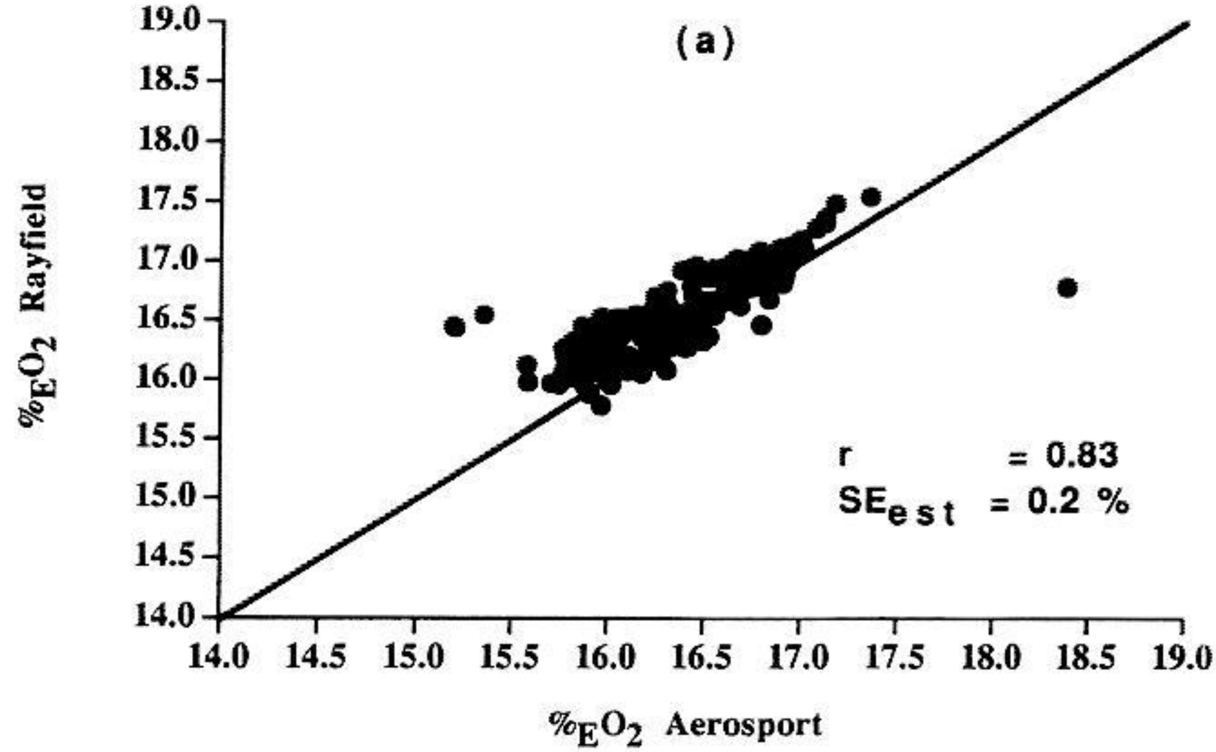
(a)
100.0
75.0
50.0
25.0
0.0
Ventilation Rayfield
(l/min, STPD)
r = 0.96
SEest = 3.7 l/min
0.0
25.0
50.0
75.0
100.0
Ventilation Aerosport
(l/min, STPD)



(b)
100.0
75.0
50.0
25.0
0.0
Ventilation Rayfield
(l/min, STPD)
r = 0.98
SEest = 4.0 l/min
0.0
25.0
50.0
75.0
100.0
Ventilation Aerosport
(l/min, STPD)

Figure 5-The relationship between ·VE measured during incremental exercise (a) and constant load exercise (b) using the Rayfield and the Aerosport TEEM 100.

Figure 6 shows the relationship between the Rayfield system and the Aerosport TEEM 100 for$\%_E O_2$ during INC (a) and CL(b) exercise. The correlations between the metabolic measurement systems were $r = 0.83$ (INC) and $r = 0.90$ (CL) and the SE_{est} were 0.2% (INC) and 0.4%(CL). While the correlations between the two systems for$\%_E O_2$ were lower than some of the other metabolic variables in this study, inspection of Tables 1 and 2 reveals that in all categories of $\cdot VO_2$, they were similar for the two systems.


(a)
19.0
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0 18.5 19.0
%EO2 Rayfield
%EO2 Aerosport
r = 0.83
SEest = 0.2 %

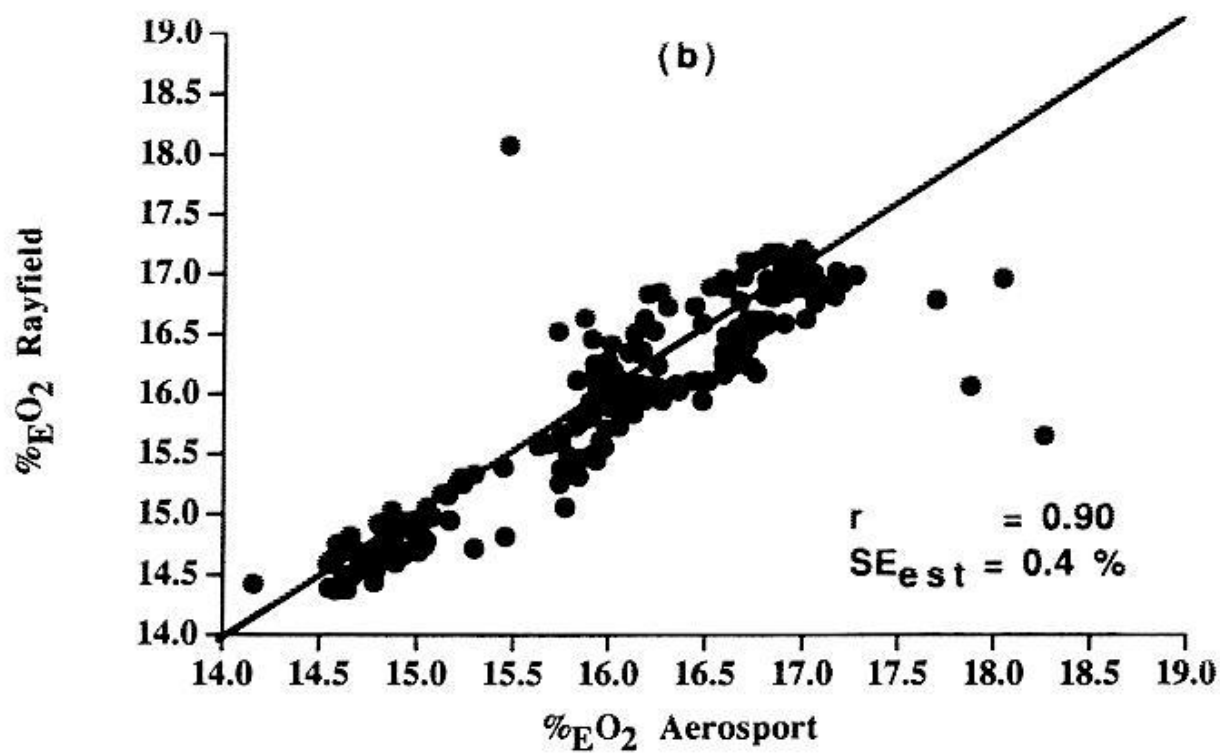

(b)
19.0
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0 18.5 19.0
%EO2 Rayfield
%EO2 Aerosport
r = 0.90
SEest = 0.4 %

Figure 6-The relationship between the%EO2 measured during incremental (a) and constant load (b) exercise, using Rayfield and the Aerosport TEEM 100.

DISCUSSION

The findings of the present study indicate that the Aerosport TEEM 100 has utility for determining $\cdot VO_2$,$\%_E O_2$, and $\cdot V_E$ during both incremental and constant load exercise, particularly for use in the field, provided that the medium flow pneumotach is used and that$\cdot V_E$ (STPD) is in the range of 3-100 $l\cdot min^{-1}$. The fact that the Aerosport TEEM 100 is portable and has the ability to run for up to 2 h on a battery, allows for the use of this system in nonlaboratory and nonresearch settings.

In contrast to previous studies of other portable metabolic measurement systems (1,2,4), the present investigation has provided $\cdot V_E$ and gas exchange comparisons between the Aerosport TEEM 100 and a previously validated system at a range of metabolic rates, up to and including maximal effort. For moderate-to-high-intensity exercise, our results suggest that the Aerosport TEEM 100 provides a more accurate determination of $\cdot VO_2$ than the Cosmed K2 system (1,4). Peel and Utsey (4) assessed the Cosmed K2 system and found a systematic underestimation of$\cdot VO_2$ at all work rates that ranged from [almost equal to]12.5% to [almost equal to]17.0%. In addition, Peel and Utsey (4) investigated only submaximal work rates, with the highest work rate eliciting [almost equal to]70% of max$\cdot VO_2$ for each subject. Lothian et al. (1) also assessed the Cosmed K2 system and found similar values for $\cdot VO_2$ at lower work rates, but a 22.2% underestimation of $\cdot VO_2$ at maximal effort compared with their criterion method. However, this study used only one subject over several days.

These previously reported differences in $\cdot VO_2$ are considerably greater than either the 6% overestimation or the 3% underestimation observed at high-intensity exercise with the Aerosport TEEM 100 for INC and CL exercise, respectively. The greatest discrepancy in $\cdot VO_2$ in the present investigation was 11% in both INC and CL exercise at $\cdot VO_2$ between 2.0 and 2.5, and 2.5 and 3.0 $l\cdot min^{-1}$, respectively. These differences were largely attributed to differences in $\cdot V_E$. It is difficult to speculate on the exact cause of differences in $\cdot V_E$ at these $\cdot VO_2$ values, but some of the error may be due to the fact that the Aerosport TEEM 100 pneumotach was used in-line with the Rayfield system. The pneumotachs for this system are designed to be used in situations where there is free flow of air across the pneumotach. At lower$\cdot V_E$, the function of the medium flow pneumotach may have been less than optimal and better results may have been obtained using the low flow pneumotach at this $\cdot VO_2$ range. Lastly, the operator's manual (3) explicitly states that no moisture should enter the sample lines or the unit. When numerous tests were completed in one afternoon, moisture in the sample lines became a problem. The manual states that moisture will impair the functioning of the unit, although the mechanism for the detrimental effects of moisture is not given. It is possible that differences in $\cdot V_E$ may have been due to moisture in the sample lines.

The reason for a consistent overestimation of $\cdot VO_2$ during INC and a consistent underestimation during CL exercise is difficult to explain. Although many data points were collected during CL exercise, the data in any given $\cdot VO_2$ category may represent only two or three subjects, due to the nature of the protocol (i.e., 30 min CL test per subject). Thus$\cdot V_E$ and $\cdot VO_2$ in a given $\cdot VO_2$ category could be influenced if data for a particular subject differed consistently in one direction.

This was the case for four of eight subjects who completed the CL protocol. That is, whereas no difference was observed between Rayfield and Aerosport in four subjects, in the other four subjects a slight but consistently higher $\cdot VO_2$ was observed for Rayfield. In contrast, during INC a greater number of subjects were evaluated at each $\cdot VO_2$ category, thus reducing the influence of a single subject on $\cdot VO_2$. Because no other studies have compared portable metabolic measurement devices using anything but INC exercise, it is impossible to speculate as to whether or not other portable devices would give similar opposing directional differences for $\cdot VO_2$ during INC and CL exercise.

The present results indicate that less confidence can be placed in $\cdot VCO_2$ and RER, primarily due to relatively large errors in $\%_E CO_2$. Therefore, use of the Aerosport TEEM 100 for estimation of the contribution of carbohydrate and fat to energy production during exercise must be questioned.

Although the Aerosport TEEM 100 system also has a low- and high-flow pneumotach available, only the medium pneumotach was used in the present study. Therefore, data from the present study do not provide validation for the low or high flow pneumotachs. Further validation studies will be needed to evaluate these pneumotachs.

REFERENCES

1. Lothian, F., M. R. Farrally, and C. Mahoney. Validity and reliability of the Cosmed K2 to measure oxygen uptake. Can J. Appl. Physiol. 18:197-206, 1993.
2. McNeill, G., M. D. Cox, and J. P. W. Rivers. The oxylog oxygen consumption meter: a portable device for measurement of energy expenditure. Am. J. Clin. Nutr. 45:1415-1419, 1987.
3. Operators Manual. Aerosport TEEM 100 Total Energy Expenditure Measurement Manual. Ann Arbor. MI: Aerosport Inc., 1993.
4. Peel, C. and C. Utsey. Oxygen consumption using the K2 telemetry system and a metabolic cart. Med. Sci. Sports Exerc. 25:396-400, 1993.