COMPARISON OF THE LACTATE PRO, LACTATE PRO 2 AND I-STAT BLOOD LACTATE ANALYSERS

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Abstract

Aim: To evaluate the accuracy of blood lactate measurements using the Lactate Pro (LP), Lactate Pro 2 (LP2) portable lactate analysers and i-STAT point-of-care device.

Methods: Blood samples (N = 284) were taken from 28 subjects during a variety of exercise modes: incremental cycling test, team-sport running simulation or resistance training. Weighted least products regression analysis was used to compare the LP to LP2 and LP2 to i-STAT.

Results: Lactate concentrations ranged between 0.4 – 18.2 mM. There was a strong linear relationship observed between the LP and LP2 analysers (r = 0.976, $p < 0.01$), although a small proportional bias was apparent. A strong linear relationship was also found between the LP2 and i-STAT analysers; however, both a fixed and proportional bias were revealed. The i-STAT reported higher absolute lactate concentrations (mean ± SD, 1.4 ± 1.3 mM, $p < 0.001$) which became more marked at moderate to high concentrations (> 4 mM; 2.2 ± 1.0 mM, $p < 0.001$).

Conclusion: While strong linear relationships existed between all three analysers, the LP and LP2 reported substantially lower lactate values compared with the i-STAT, especially at higher lactate concentrations. These results further highlight the need for caution when interpreting or comparing lactate data obtained using different analysers.

Keywords:

Lactate, Lactate analysis, Point-of-care testing,

Introduction:

Blood lactate is commonly used by athletes, coaches, and researchers to evaluate exercise intensity and predict performance. Changes in lactate thresholds are more sensitive to alterations in training status[1] and provide a better indication of endurance performance than VO_2max[2]. The increase in availability of reliable and inexpensive portable lactate analysers has subsequently allowed field-based monitoring of lactate concentrations to become routine. In contrast, field-based measurement of other blood parameters related to performance, such as pH, bicarbonate and blood gases have largely been restricted due to the need for specialised, laboratory based equipment.

The i-STAT (Abbott Point of Care Inc, Princeton, NJ) is a handheld, portable analyser capable of measuring a range of parameters in relatively small blood samples (95 µL). These features, along with self-calibration, an internal error detection system, and rapid reporting of results make it an attractive tool for field-based testing. When used in conjunction with a CG4+ cartridge, measures of lactate, pH, PCO_2, and PO_2, as well as calculated values for total CO_2, bicarbonate, base excess and oxygen saturation can be obtained from a single blood sample. Previous studies have found the i-STAT CG4+ to be accurate and reliable in both clinical[3, 4] and exercise settings[5] but limited information is available comparing lactate results obtained using the i-STAT with those of other portable lactate analysers[3, 5]. While it is standard laboratory practice to use a single analyser for any given experiment, within a laboratory different analysers may be used between studies depending on the experimental variables of interest. It is, therefore, important to understand the relationship between results obtained using different analysers in order to prescribe appropriate exercise intensities and interpret results from different studies with confidence.

The Lactate Pro (LP) is a commonly used portable lactate analyser that employs an enzymatic, amperometric system to detect lactate concentrations in blood. Recently the LP has been superseded by the Lactate Pro 2 (LP2) which requires less blood, calibrates automatically, has an extended detection range and generates results within 15 s. While a number of researchers have compared the LP to a range of other portable lactate analysers[6-12], to the best of our knowledge there is only one published report comparing the performance of the LP2[13]. Therefore, the purpose of this study was to compare the lactate concentrations obtained from blood samples taken across a range of exercise intensities using the i-STAT, LP and LP2.

Materials and Methods:

Subjects

Twenty eight recreationally active, Caucasian individuals, between the ages of 19 and 41 were recruited to participate in the study. Informed, written consent was provided by all subjects prior to taking part in the experiment, which was approved by the Australian Catholic University Human Research Ethics Committee (2013 328V) and conducted in accordance with the Declaration of Helsinki.

Experimental Design

Blood samples (n = 284) from finger prick (n = 263) and venous blood draws (n = 21) were obtained from subjects during an incremental bicycle exercise test, team-sport running simulation or resistance training session. The blood samples used for the different comparisons were divided as follows:

1. LP v LP2 (n = 75; venous n = 21, capillary n = 54)
2. LP2 v i-STAT (N = 241; all capillary samples)

Venous blood samples were initially collected into evacuated tubes (#454071, Greiner Bio-one International, Thailand) from a median forearm vein. An aliquot was then immediately analysed by pipetting the sample onto the LP and LP2 test strips.

To promote blood flow during finger prick sampling, the subjects' hands were placed in warm water for ~10 s immediately prior to sampling. Hands were dried thoroughly, swabbed with alcohol and the skin punctured using a disposable lancet. The first drop of blood was excluded from the sample. Two heparinised capillary tubes were used to collect the 95 µL of whole blood required for analysis using the i-STAT. The non-haemolysed sample was handed to a second investigator who immediately transferred it to a CG4+ cartridge (Abbott Point of Care, Princeton, NJ) for analysis. Blood from the same puncture site was applied directly from the finger to the LP and LP2 test strips (Arkray Inc, Kyoto, Japan) immediately following the completion of capillary collection. All blood collections were completed in < 45 s.

Lactate Analysers

The same individual LP, LP2 (Arkray Inc, Kyoto, Japan) and i-STAT (Abbott Point of Care Inc, Princeton, NJ) units were used to test all blood samples. All units were calibrated according to the manufacturer's instructions prior to each testing session. Calibration verification of individual CG4+ cartridge lots were performed using level 1 and 3 controls (Abbott Point of Care, Princeton, NJ).

Practical Implications

Representative blood lactate data, previously collected during an incremental cycling test[12], were used to determine the practical implications the use of different analysers may have on the prescription of exercise intensity. Data were assumed to have been collected using the

LP2 and the lactate values modified using the appropriate regression equations. Blood lactate parameters, including lactate threshold, DMax, fixed blood lactate concentrations at 4 mM and 3.5 mM, fixed rise in lactate of 1 mM above baseline, and the log-log transformation of lactate threshold were then assessed using the Lacate-E macro for Microsoft Excel[14].

Statistical Analysis

Data were analysed using the Statistical Package for Social Sciences version 20.0 (IBM Corporation, Armonk, NY, USA) and presented, where appropriate, as means ± standard deviations. A Student's paired *t*-test was used to determine the mean difference between analyser results. The presence of heteroscedasticity in the data was confirmed by both visual inspection and the Koenker test. Therefore, to account for the heteroscedasticity the relationships between the different analysers were assessed using Pearson's correlation coefficient and weighted least products regression[15].

Results:

Lactate concentrations in the blood samples assessed by the different analysers ranged between, 0.8-13.2 mM, 0.7-14.8 mM and 0.4-18.2 mM for the LP, LP2 and i-STAT, respectively. A strong linear relationship was observed between the LP and LP2 analysers (Table 1). Despite no fixed bias being observed between the two analysers, there was a proportional bias; although this appeared to be small, with the mean difference increasing from 0.3 ± 0.4 mM in samples with concentrations of < 4mM to 0.4 ± 0.8 mM in samples with concentrations ≥ 4 mM.

A strong linear relationship was also found between the LP2 and i-STAT analysers; however, both a fixed and proportional bias were revealed. The i-STAT consistently reported higher absolute lactate concentrations (1.4 ± 1.3 mM, $p < 0.001$) which became more marked at

moderate to high concentrations (> 4 mM; 2.2 ± 1.0 mM, $p < 0.001$). The bias between the analysers at concentrations < 4 mM was small, but significant (0.4 ± 0.8 mM, $p < 0.001$).

Figure 1 and Table 1

Differences in lactate markers, calculated using the spreadsheet from Newell et al (2007) revealed no differences in lactate threshold determined using either raw or log data (Figure 2 and Table 2). Similarly, the endurance marker, DMax did not vary between all three analysers. Markers that corresponded to fixed blood lactate concentrations or fixed increases from baseline did, however, vary with the i-STAT consistently reporting lower workloads for each benchmark (Table 2).

Figure 2 and Table 2

Discussion:

Point-of-care analysers, such as the i-STAT, allow the easy and relatively inexpensive measurement of a range of blood parameters, including lactate. However, few studies have reported on the accuracy of point-of-care lactate measurements in relation to other portable lactate analysers. Results from the current study indicated that while a strong linear relationship existed between the i-STAT and LP2, a fixed and proportional bias was also observed between the two devices, resulting in substantial differences in the workloads associated with fixed blood lactate measures.

No criterion measure for lactate currently exists. Subsequently, we chose to compare the i-STAT with the LP2, the predominant method of lactate measurement in our laboratory. The LP2 has recently replaced the popular LP analyser. Whereas several studies have reported

the accuracy and reliability of the LP[6-12] there is, to our knowledge, only one study that has compared the LP and LP2[13]. Bonaventura et al (2015) compared the performance of both the LP and LP2 against the Radiometer ABL90 and demonstrated the LP2 had a reduced bias, especially at lactate concentrations above 10 mM. In contrast, here we report a significant linear relationship exists between the two portable analysers, albeit one that is associated with a small proportional bias; indicating the LP2 slightly under estimates lactate relative to the LP. The reason for the discrepancy in these findings is unclear. While ~75% of the blood samples used for comparing the LP and LP2 in the current study were taken from the fingertip sequentially, rather than in parallel, the order in which the samples were taken was randomised and the time between samples < 5 s, making it unlikely sample order contributed to the difference.

The results from the current study indicated a strong linear relationship existed between lactate concentrations obtained using the i-STAT and LP2. However, both a fixed and proportional bias was present. Strong linear relationships have been previously reported between the i-STAT and laboratory-based analysers[3, 4]. Although absolute agreement between the i-STAT and other analysers is less consistent, with both good[4, 5, 13] and poor[3] levels of agreement being reported when comparing the i-STAT to portable[5] and laboratory based[3, 4, 13] analysers. Here we found the i-STAT consistently reported significantly higher lactate concentrations, especially once lactate exceeded 4 mM. Whereas Dascombe et al (2007) reported a good agreement between the i-STAT and Accusport analysers, our results found lactate concentrations to be ~27% higher when measured by the i-STAT compared to the LP2, reflecting a similar pattern to those reported by Bonaventura et al (2015). Such large disparity in absolute lactate concentrations between analysers is a consistent finding within the literature [3, 6, 9, 11] highlighting the difficulty associated with interpreting data obtained using different analysers.

It is possible the disparate results between the LP2 and i-STAT are due in part to red blood cells either being or not being lysed as part of the measurement process. Lactate concentrations are higher in plasma compared with whole blood and red blood cells[16]. The LP has previously been shown to lyse blood[7] and would therefore be expected to report lower lactate values than the i-STAT, which measures plasma lactate[17]. While the lower lactate values observed in the current study support the idea that the LP2 also lyses blood as part of its measurement process, this hypothesis has yet to be directly tested.

Despite the lack of absolute agreement between the different analysers the impact on lactate thresholds based on relative changes in lactate concentration was minimal. No shift was observed in the threshold when it was identified using DMax, LT or $LT_{(loglog)}$ using any of the three analysers. However, differences in power between the LP2 and i-STAT analysers of 14 to 19 W were calculated for thresholds obtained using fixed blood lactate concentrations. Smaller differences of 6-7 W were calculated between the LP and LP2 analysers. As a consequence, switching between the different analysers could shift fixed blood lactate thresholds by 3-15% resulting in either an overestimation or underestimation of an individual's ability. Consequently, consistent use of analysers, reported margins of error and cautious interpretation of comparative results should remain at the forefront of research involving different portable lactate analysers and point-of-care devices.

Conclusions

In conclusion, the i-STAT provides a number of blood variables of interest to exercise scientists in addition to lactate. Whereas a strong linear relationship exists between the i-STAT and LP2, caution must be taken when interpreting absolute data obtained from the different analysers as the i-STAT provides markedly higher lactate concentrations.

Any measures reliant upon absolute lactate concentrations (e.g., onset of blood lactate accumulation) would clearly produce different results in terms of power output, treadmill velocity or heart rate[6, 11].

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Titles of Figures

Figure 1

The relationship between the (A) Lactate Pro 2 and Lactate Pro, and (B) Lactate Pro 2 and i-STAT portable lactate analysers. Dotted line = line of identity.

Figure 2

Comparison of blood lactate versus power output for the Lactate Pro, Lactate Pro 2 and i-STAT portable devices, using a representative cycling data set.

Table I: Weighted least product regression and 95% confidence intervals (CI) for comparisons of lactate levels obtained using Lactate Pro (LP), Lactate Pro 2 (LP2) and i-STAT devices.

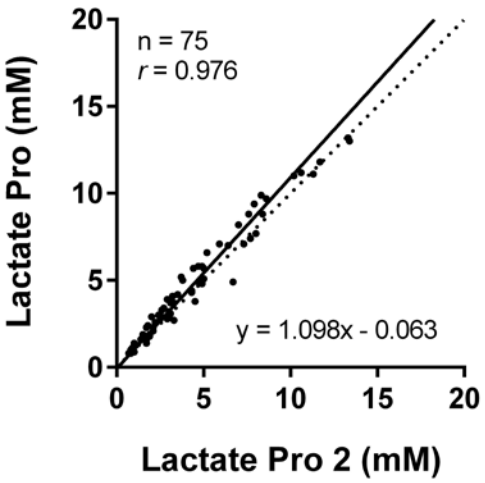
Portable Lactate Analysers	n	intercept	95% CI	slope	95% CI	r	Fixed bias	Proportional bias
LP2 v LP	75	-0.063	[-0.299–0.162]	1.098	[1.0430-1.156]	0.976*	N	Y
LP2 v i-STAT	241	-0.776	[-1.193-0.383]	1.453	[1.372-1.538]	0.894*	Y	Y

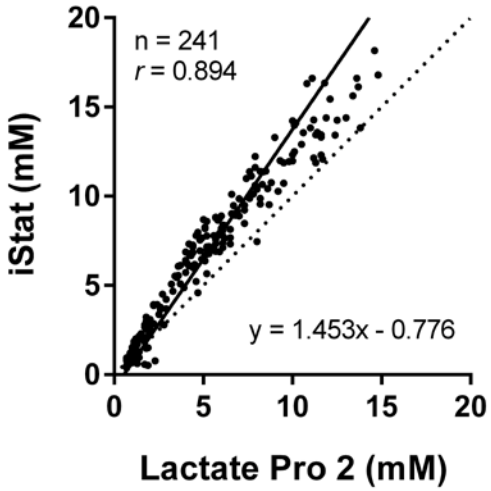
*Significant at $P < 0.01$

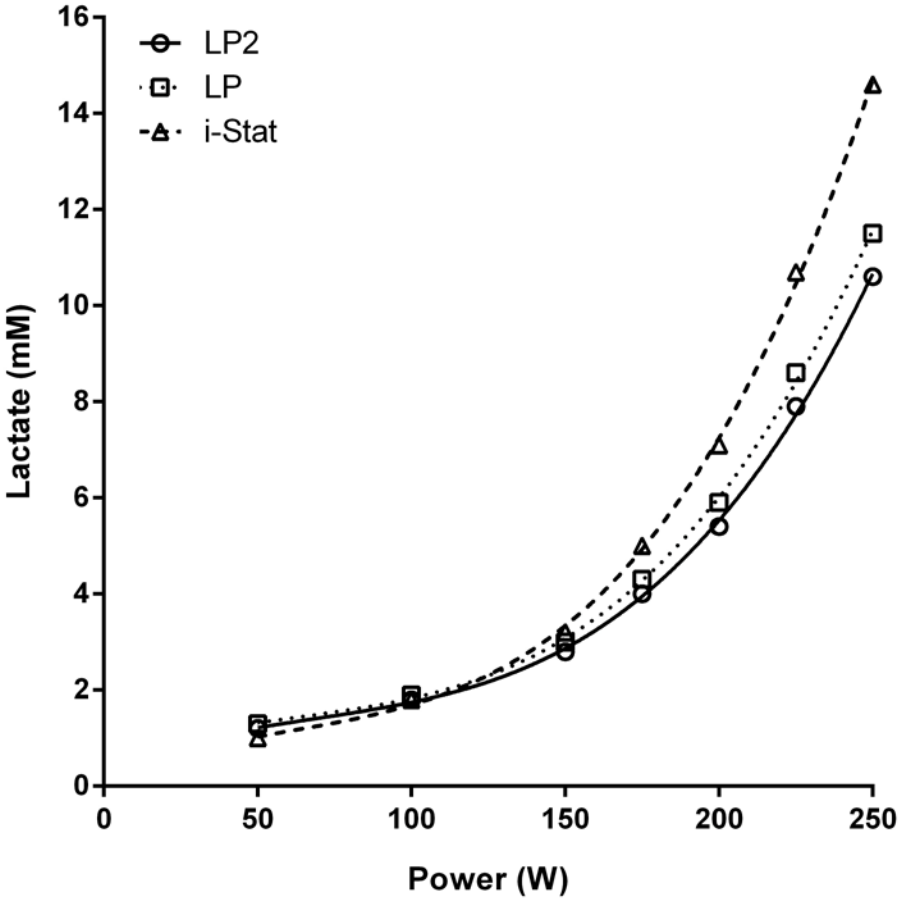
Table II: Predicted workloads for different lactate markers of endurance performance.

	Power (W)					
	FBLA		FRPB			
	4 mM	**3.5 mM**	**1 mM**	**DMax**	**LT**	**$LT_{(loglog)}$**
LP	170	160	116	167	185	140
LP2	176	166	123	167	185	140
i-STAT	161	152	104	167	185	140

Threshold calculations performed using the method of Newell et al (2007) using representative cycling data[14]. FBLA = Fixed blood lactate concentration; FRPB = Fixed rise post baseline; LT = lactate threshold.


n = 75
r = 0.976
y = 1.098x - 0.063
Lactate Pro (mM)
Lactate Pro 2 (mM)
0
5
10
15
20


n = 241
r = 0.894
y = 1.453x - 0.776
iStat (mM)
Lactate Pro 2 (mM)
0
5
10
15
20


LP2
LP
i-Stat
Lactate (mM)
Power (W)
0
2
4
6
8
10
12
14
16
0
50
100
150
200
250