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Lactate Testing Revisited: A Reliable Indicator of Training Progress for All Swimmers

Stasinios Stavrianeas and AI Stephenson

We examined the use of lactate testing to monitor training progress in swimming at a small liberal arts college, using an inexpensive handheld lactate analyzer. The tests were carried out by undergraduates as part of their investigative learning curriculum in exercise science. Twelve female athletes participated in a 2-year program of periodic testing using a 5 × 200 swim of increasing intensity. Blood lactate values were measured from a sample obtained 2–4 min after each swim, plotted against swim time, and the maximal lactate steady state (MLSS) was identified. MLSS improved significantly throughout the training period (higher by 0.56 mmol/L and lower by 5.92 s, $p < .05$), accompanied by significant improvements in swim performance in middle distances. We conclude that the use of a handheld lactate analyzer is an effective method to monitor training progress in swimming. The low cost of the procedure and the participation of undergraduate students were novel applications of established protocols.

Key Words: adult swimming, swim training, swimming, aquatic fitness

Lactic acid is a by-product of the work performed by the active muscles during exercise. Measurements of blood lactate levels have long been used as markers of exercise intensity and training progress in competitive swimming, and there are numerous lactate-testing protocols and procedures for competitive athletes. Given the complexity of the parameters involved, considerable controversy surrounds the actual value of these lactate measurements for predicting performance in swimming or monitoring degree of exertion or recovery from intense exercise. It appears, however, that the periodic use of lactate measurements is unequivocally accepted as a measure of training progress (Smith, Norris, & Hogg, 2002). In other words, blood lactate profiles obtained through standardized testing protocols are being used by coaches and athletes as markers of progress made through a training cycle or as means to determine training intensities (Maglischo, 1993). Such techniques and protocols have been available for almost 30 years, and their use is commonplace at facilities with specialized scientific personnel, graduate assistants, or research laboratories.

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Unfortunately, not all swimmers benefit from such training aids, as the literature offers few but bright insights into the physiological measurements associated with Masters swimmers (Mattern et al., 2003; Reaburn & Mackinnon, 1990; Shephard, Kavanagh, Mertens, Qureshi, & Clark, 1995; Tuuri, Keenan, West, Delany, & Loftin, 2005). The United States Masters Swimming organization defines Masters athletes as being 18 or over and committed to maintaining a physically active lifestyle for fitness or athletic competition (United States Masters Swimming, 2006). It is a testament to the quality of the training and the high level of competition that organized swim meets are officially sanctioned by the swimming governing bodies. It is the responsibility of the scientists, coaches, and training staff to provide the highest level of support for these athletes, who work hard to maintain their health and fitness level well into older age. It must be noted that, although some limited work has been conducted in this area, there is much yet to be learned regarding, for example, the best training techniques at various ages, the relationship between training intensity and aging, and the social and psychological factors that influence training and performance for Masters athletes (e.g., Donato et al., 2003). It is apparent that the availability of training aids will greatly benefit this large population of swimmers, and every effort should be made to increase their accessibility to such resources.

At the same time, it is the responsibility of educators to train the next generation of scientists, clinicians, coaches, and teachers who will be asked to reverse the current trend toward inactivity, obesity, and associated diseases that affect our population. This should be accomplished through transformation of the traditional physical education program of study to a modern exercise-science curriculum, grounded in the latest guidelines in science education. The current standards in science education require investigative experiences for all students, and it is only appropriate to use every possible educational opportunity to include them in the research experience (Stavrianeas & Harmer, 2006).

Given the fact that many swimmers often lack quality data regarding their training and the need to expose undergraduate students to investigative learning, the main objective of this study was to combine these two objectives by providing undergraduate students with research experiences designed to evaluate the effectiveness of a 2-year training program for swimmers at a small NCAA Division III liberal arts college. I hoped that such measurements would be meaningful and useful to the athletes and their coaches, that the tests would be cost-effective and easy to administer, and that the undergraduate students would benefit greatly from this learning opportunity as they prepare for the next step in their education or professional careers.

Methods

Twelve female college swimmers (age 19 ± 1.2 years) were classified as sprinters (mainly competing in distances less than 200 yd) and endurance swimmers (mainly competing in events longer than 200 yd). The athletes participated in this testing program over a 2-year period. The tests were performed three times during each swimming season, in early December shortly after the team started practicing, in mid- to late January right after their training camp, and in late February before their

taper period. The swimmers initially performed a 5 × 200 yd swim at progressively higher intensity (Smith et al., 2002), starting at 60% effort and concluding with 100% effort, with rest intervals of approximately 6 min between swims. At the end of each swim the athletes' heart rate was measured via palpation and recorded.

Approximately 2–4 min after the end of the swim a small blood sample was obtained from a hyperemized earlobe through a heparinized capillary tube (Pyne, 1989). The blood was then transferred onto disposable lactate strips and analyzed with the use of the Roche Accusport™ Lactate analyzer. The lactate values were recorded, and the results were plotted using Microsoft® Excel® software for the visual identification of the point to be referred to as individual maximal lactate steady state (MLSS), otherwise also known as lactate threshold (LT; see discussion in Weltman, 1995, and references therein). In subsequent tests the range of intensities was narrower, allowing for a more precise determination of the MLSS. All tests were conducted at the same time of the day and immediately after warm-up to prevent fluctuations in glycogen levels known to influence lactate values (Ivy, Costill, & Maxwell, 1980).

The LT values and corresponding swim times for each training phase were compared using ANOVA ($\alpha = .05$). The training intensities averaged from the coach's training log were analyzed for possible correlations between training intensity and improvements in MLSS. All tests were designed and conducted by undergraduate students under my supervision.

Results

Three of the 12 athletes completed the entire 2-year testing cycle, and 9 swimmers completed all the tests for at least one season. These athletes missed one or more session because of illness, injury, or family reasons. The testing protocol yielded a desirable blood lactate curve that allowed for determination of the LT (Figure 1). The long layoff from swimming practices associated with a Division III swimming program at a small liberal arts school prevented any conclusions regarding the progression of training from one year to the next. On the other hand, the data yielded significant information regarding the quality of the training program within a single season.

The testing dates corresponded to different phases of training, a fact reflected in the lactate curves (Figure 2). More specifically, for the first year of training, the average lactate value at MLSS improved by 0.34 mmol/L from December to January and another 0.26 mmol/L from January to February, for a total improvement of 0.56 mmol/L. Accordingly, the average swim time at MLSS decreased by 3.06 s from December to January and an additional 2.86 s from January to February, for a total decrease of 5.92 s in the 200-yd swim. The results of an ANOVA comparison yielded significant differences between the three dates for both lactate values at MLSS and swim time at MLSS ($\alpha = .05$), indicating that the training program was successful at improving swim times at MLSS. The values were very similar for the second year, but, unfortunately, these results were not additive.

The relative training intensities for the four different training periods in a season are presented in Table 1. Training intensities were prescribed based on heart-rate responses to maximal effort in the water. It was not possible to identify

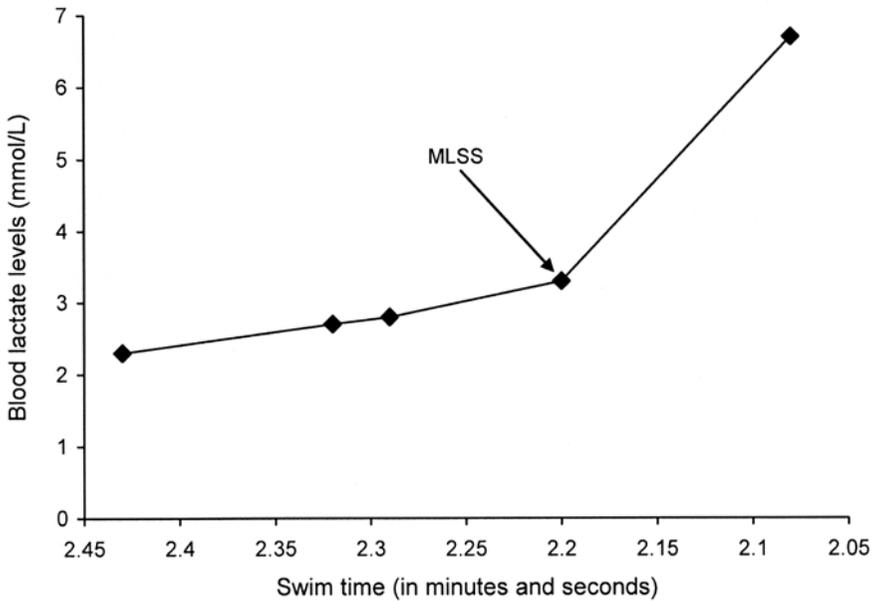


Figure 1 — A typical blood lactate curve. The lactate break point that corresponds to maximal lactate steady state (MLSS) is identified as the first significant upward deflection from baseline.

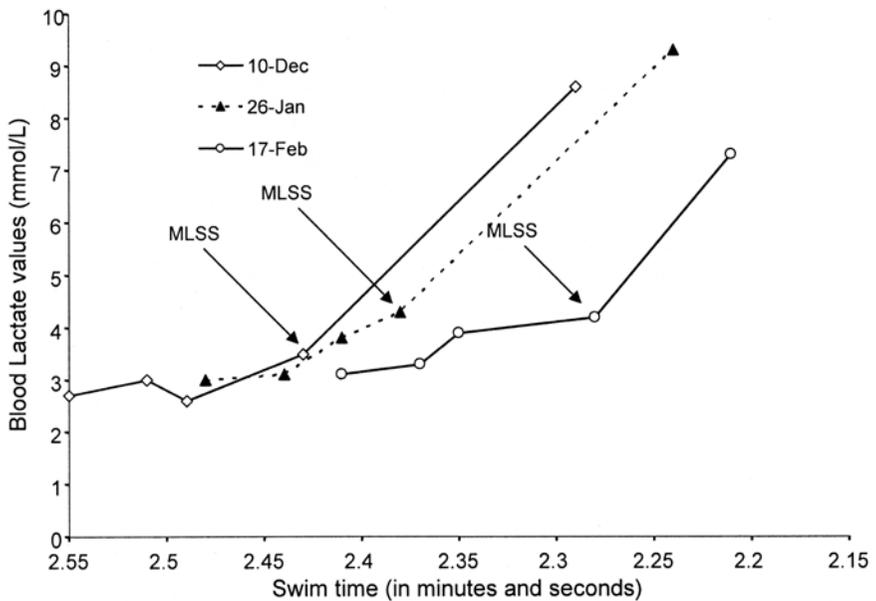


Figure 2 — Improvements in aerobic conditioning resulting from training were documented throughout the season, as the maximal lactate steady state (MLSS) was achieved at higher swim velocities and higher lactate values.

Table 1 Distribution of Training Intensities Throughout the Different Phases of the Competitive Season

	Low intensity (<65% of maximum)	Intermediate intensity 1 (slightly below the MLSS)	Intermediate intensity 2 (slightly above the MLSS)	High intensity (>90% of maximum)
Nov–Dec	50%	20%	20%	10%
Dec–Jan	20%	30%	30%	20%
Jan–Feb	10%	30%	40%	20%
Feb–Mar	10%	20%	40%	30%

Note. During the early part of the season general conditioning is emphasized, whereas in the latter part of the season training intensity increased considerably. The relationship is inversely related to the total distance per workout (data not shown). MLSS = maximal lactate steady state.

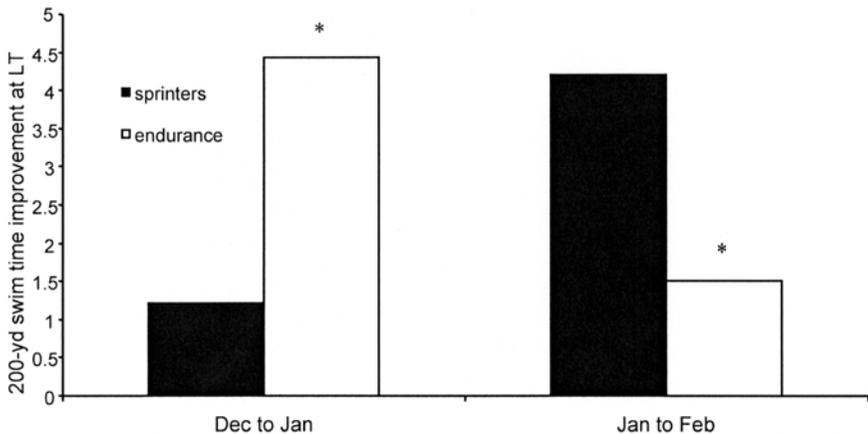


Figure 3 — The characteristics of total improvement in maximal lactate steady state (MLSS) were identical in sprinters and distance swimmers, although the bulk of the improvement occurred in different phases of their training season. LT = lactate threshold. * $p < .05$.

any relationship between training intensity and improvements in MLSS, although it was interesting to notice that sprinters exhibited a different pattern of improvement from the distance swimmers (Figure 3). A Student's t -test comparison ($\alpha = .05$) revealed differences between the two groups in the timing of the improvements in MLSS.

The total monetary expense for the entire project was less than \$750, which makes this a relatively inexpensive means to evaluate training progress. Student responses to questionnaires designed to assess their experience and learning outcome reveal a high degree of satisfaction with the experience. Much to our liking, students were able to make connections between the theoretical concepts discussed in the classroom and the practical and methodological issues associated with these tests. An additional benefit was the degree of excitement generated among the

students and the swimmers as the “experimenters” frequently interacted with their “participants” to discuss the outcomes of the experiments and exchange information regarding the physiological adaptations associated with training.

Discussion

This study was designed to satisfy two objectives: to explore the use of a low-cost procedure that allows for the monitoring of blood lactate levels for the purpose of improving training in swimming and to expose students in the field of exercise science to the scientific investigative method. The study satisfied both objectives in that students were able to collect and analyze data of high quality. Furthermore, the data were useful to coaches, who were able to better adjust training intensities throughout the training season, and to swimmers, who gained appreciation for the design of training programs. As an added benefit, most swimmers improved their personal times in distances of 200 yd or longer. Because this study did not consider improvements in maximal lactate production and removal, it is not possible to relate our measurements to performance in sprinting events.

Lactate measurements can be conducted during training using portable lactate analyzers. Several such models have existed for a number of years, and most have been validated against more sophisticated enzymatic laboratory protocols. During the pilot phase of this project students compared blood lactate values obtained simultaneously using three separate Accusport lactate analyzers. There were no statistical differences between the three devices ($\alpha = .05$), and the data were highly correlated ($.94 < r < .97$). In order to quantify how narrow the margin of error was, students conducted a brief series of experiments comparing the values from the Accusport units with those of a commercially available spectrophotometric assay (Sigma protocol UV 826). Results indicated a high correlation ($r = .87$) between the two measurements. These results are analogous to the work of Pinnington and Dawson (2001), who validated the Accusport analyzers against the Analox LM3 lactate analyzer, and of Brinkert, Rommes, and Bakker (1999), who validated the use of this specific analyzer in the clinical setting.

The design of the testing protocol was appropriate, in that the individual maximal lactate steady state was easily identified in each test. Furthermore, the procedure allowed for easy assessment of fitness improvements throughout the course of the training period. The obvious benefit of such tests is that coaches and swimmers can establish target training intensities, and these targets can be updated as the athletes improve their performance. This periodic assessment of progress can be made reliably at a reasonable cost and with a reasonable degree of confidence.

Regular physical activity and proper nutrition are the hallmarks of a healthy lifestyle for people of all ages. After the decline of physical education programs in schools and the subsequent alarming rise in childhood obesity and associated diseases, several initiatives have been launched on a regional and national level to promote physical activity. Although many plans target children and teens, other programs provide avenues to adults who wish to engage in exercise programs to increase or maintain their fitness levels or even compete in sports. For example, the American Medical Association consistently reinforces its campaign to promote physical activity throughout the life cycle (Brender, Burke, & Glass, 2006; Torpy,

Lynn, & Glass, 2005). The beneficial effects of regular involvement in exercise for fitness or competition for Masters athletes are clearly demonstrated in the work of Shephard and colleagues (1995) and others (Galloway & Jokl, 2000). Organizations such as United States Masters Swimming provide resources, support, and guidance for thousands of adults who maintain their health and fitness through swimming (www.usms.org/about.php; Hastings, Cable, & Zahran, 2005). Furthermore, sociological research indicates that Masters swimmers are just as motivated as elite athletes in choosing to be physically active and to fulfill their social identity through their involvement in swimming (Stevenson, 2002). It is clear that a coordinated effort at promoting an active lifestyle across the lifespan must include education of the public, availability of facilities, and qualified personnel to assess progress, design exercise programs, and ensure the safety of the participants (Miller, 1999).

In this project, exercise-science students used the scientific investigative method to demonstrate that it is possible and cost-effective to monitor markers of training progress in swimming. It must be stated that the procedures and equipment used in this project were not novel. On the other hand, the facts that this project was conducted by undergraduate students, it was easy to administer, and it yielded information that was valuable and important to swimmers and athletes cannot be understated. We have demonstrated that it is possible for all recreational and Masters swimmers to use a similar approach to monitor their training. Collaboration with students from local schools is one of the potential avenues that can be explored.

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References

- Brender, E., Burke, A.E., & Glass, R.M. (2006). Fitness for older adults. *Journal of the American Medical Association*, 296, 242.
- Brinkert, W., Rommes, J.H., & Bakker, J. (1999). Lactate measurements in critically ill patients with a hand-held analyzer. *Intensive Care Medicine*, 25, 966-969.
- Donato, A.J., Tench, K., Glueck, D.H., Seals, D.R., Eskurza, I., & Tanaka, H. (2003). Declines in physiological functional capacity with age: A longitudinal study in peak swimming performance. *Journal of Applied Physiology*, 94, 764-769.
- Galloway, M.T., & Jokl, P. (2000). Aging successfully: The importance of physical activity in maintaining health and function. *Journal of the American Academy of Orthopaedic Surgeons*, 8, 37-44.
- Hastings, D.W., Cable, S., & Zahran, S. (2005). The globalization of a minor sport: The diffusion and commodification of masters swimming. *Sociological Spectrum*, 25, 133-154.
- Ivy, J.L., Costill, D.L., & Maxwell, B.D. (1980). Skeletal muscle determinants of maximum aerobic power in man. *European Journal of Applied Physiology and Occupational Physiology*, 44, 1-8.

- Maglischo, E.W. (1993). *Swimming even faster*. Mountain View, CA: Mayfield Publishing.
- Mattern, C.O., Gutilla, M.J., Bright, D.L., Kirby, T.E., Hinchcliff, K.W., & Devor, S.T. (2003). Maximal lactate steady state declines during the aging process. *Journal of Applied Physiology*, 95, 2576-2582.
- Miller, J.W. (1999). Injuries and considerations in masters aquatics sports. *Clinician and Sports Medicine*, 18, 413-26.
- Pinnington, H., & Dawson, B. (2001). Examination of the validity and reliability of the Accusport blood lactate analyser. *Journal of Science and Medicine in Sport*, 4, 129-138.
- Pyne, D.B. (1989). The use and interpretation of blood lactate testing in swimming. *Excel*, 5(4), 23-26.
- Reaburn, P.R.J., & Mackinnon, L.T. (1990). Blood lactate responses in older swimmers during active and passive recovery following maximal sprint swimming. *European Journal of Applied Physiology*, 61, 246-250.
- Shephard, R.J., Kavanagh, T., Mertens, D.J., Qureshi S., & Clark, M. (1995). Personal health benefits of Masters athletics competition. *British Journal of Sports Medicine*, 29, 35-40.
- Smith, D.J., Norris, S.R., & Hogg, J.M. (2002). Performance evaluation of swimmers. *Sports Medicine*, 32, 539-554.
- Stavrianeas, S., & Harmer, P. (2006). Destination Bio2010: Taking the road less traveled. *CUR Quarterly*, 26, 164-168.
- Stevenson, C.L. (2002). Towards an understanding of the athletic careers of masters swimmers. *International Review for the Sociology of Sport*, 37, 131-146.
- Torpy, J.M., Lynn, C., & Glass, R.M. (2005). Fitness. *Journal of the American Medical Association*, 294, 3048.
- Tuuri, G., Keenan, M.J., West, K.M., Delany, J.P., & Loftin, J.M. (2005). Body water indices as markers of aging in male masters swimmers. *Journal of Sports Science and Medicine*, 4, 406-414.
- United States Masters Swimming. (2006). Retrieved September 6, 2006, from www.usms.org.
- Weltman, A. (1995). *The blood lactate response to exercise*. Champaign, IL: Human Kinetics.