

Appendix A

Beneke, R. (1995). Anaerobic threshold, individual anaerobic threshold, and maximal lactate steady state in rowing. *Medicine and Science in Sports and Exercise*, 27, 863-867.

This study measured the MLSS in male rowers. Thirty-minute constant load sessions were used to determine the MLSS by analyzing blood lactate via earlobe puncture numerous times over the course of the workout. The purpose was intended to compare where the anaerobic threshold (as defined by 4.0 mmol•L⁻¹ blood occurred) and individual anaerobic threshold (IAT) occurred versus MLSS as it relates to VO₂. The AT 4.0 mmol•L⁻¹ and IAT were found at statistically higher intensities than the MLSS. This indicates that the lactate (or anaerobic) threshold of individuals occurs higher than the steady state or sustainable effort of exercise. This is of course relative to rowing, but there is a trend noted that the LT itself will be a higher intensity than can be maintained over a long period of time.

Beneke, R., Hutler, M., & Leithauser, R.M. (2000). Maximal lactate-steady-state independent of performance. *Medicine and Science in Sports and Exercise*, 32, 1135-1139.

They showed that the MLSS is not related to MLSS workload or peak workload. There was no relationship between the variables, showing that the MLSS was not predicted or related to the amount of work an individual can perform. There was a relationship between peak workload performed and the MLSS workload, meaning, the higher the peak workload, the higher the overall MLSS workload. More fit individuals can do more sustained work efforts at higher intensities.

These MLSS articles show the work that would be necessary to identify the MLSS, which we will not do at this time. It is logical after determining LT land versus water to investigate the MLSS to see if equivalent intensities can be maintained land versus water.

Benelli, P., Massimiliano, D., & De Vito, G. (2004). Physiological responses to fitness activities: a comparison between land-based and water aerobics exercise. *Journal of Strength and Conditioning Research*, 18, 719-722.

A comparison was made between land and water aerobics, blood lactate being one of the variables examined. Due to the buoyancy effect in the water, there tended to be a lower overall intensity as made plain by lower blood lactate levels HR. The aerobics exercises were controlled by speed and were performed on land, shallow water (waist level), and deep water (neck level).

This article is a great example as to why jet resistance is so critical in comparing land and water activities. The same relative workload land and water will never be equivalent, so a way needs to be determined to elicit the same exercise intensity.

Bentley, D.J., Newell, J., & Bishop, D. (2007). Incremental exercise test design and analysis. *Sports Medicine*, 37, 575-586.

This review article shows a comparison of the methodology involved with lactate threshold as well as the identification of the point of threshold. After examining articles with continuous and discontinuous protocols and varying times for each stage, the authors determined that 3-minute stages using continuous protocol gives the most valid and reliable measures of endurance performance.

The information obtained in this article helped to identify that 3-minute stages of a continuous protocol was optimal to determine LT. In order to remain consistent between two LT tests, all variables leading up to the LT test should be the same. Subjects should not introduce anything extreme into their diets.

There is a discussion in this article about first and second LT or VT points that occur. If there are controversial LT's that occur during this study, this would be a great reference to identify variables that could help to explain changes in blood lactate values as workload increases.

Bressel, E., Smith, G., Miller, A., & Dolny, D. (2012). Aquatic-treadmill walking: quantifying drag force and energy expenditure. *Journal of Sport Rehabilitation*, EPUB, PMID 22715134, ahead of print.

This article is the first to quantify the amount of drag force that comes from the jets at varying intensities. Along with quantifying that data, walking VO_2 was obtained from subjects while jet intensities were increased from 0% to 80% of maximum. The VO_2 obtained at the same walking speed with 0% and 80% jets was doubled ($11.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $22.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ respectively). With the ability to double energy expenditure with jet resistance, there is a tremendous benefit for rehabilitative purposes to keep patients at slower walking or jogging speeds and increasing metabolic demand via the jet resistance.

Using the drag force data can help in calculations of energy expenditure from a mechanical standpoint. In other words, researchers will now be able to do mechanical analysis of walking or running and use jet intensity.

Brubaker, P., Ozemek, C., Gonzalez, A., Wiley, S., & Collins, G. (2011). Cardiorespiratory responses during underwater and land treadmill exercise in college athletes. *Journal of Sport Rehabilitation*, 20, 345-354.

Subject population consisted of older/middle-aged non-athletic women. Underwater versus land treadmill submaximal intensities were compared. The test was progressive in nature with the condition (land or water) being randomized. They refrained from eating or drinking for 3 hours prior to tests and avoid strenuous activity for 24 hours. At a speed of $7.3 \text{ km}\cdot\text{h}^{-1}$ there was found statistically higher VO_2 , HR, and tidal ventilation on land than in the water. Also at $9.6 \text{ km}\cdot\text{h}^{-1}$ was found statistically higher VO_2 on land than in water. The authors state that the reduced metabolic cost in the water is attributed to the buoyancy force of the water, lightening the physical load on the subjects.

It was determined that the HR- VO_2 relationship remained constant between the two modalities with a linear trend being shown (UTM was $r=.94$ and LTM was $r=.95$). Along with the HR discussion, there were no differences between perceived exertion land versus water conditions, despite lower VO_2 values in the water at the faster speeds in this study.

Bushman, B.A., Flynn, M.G., Andres, F.F., Lambert, C.P., Taylor, M.S., & Braun, W.A. (1997). Effect of 4 weeks of deep water run training on running performance. *Medicine and Science in Sports and Exercise*, 29, 694-699.

The methods in this article have some citations that may be useful. The purpose of this study was to see if on land running performance (as measured by a 5 kilometer time trial on an automatically speed controlled treadmill) could be maintained after 4 weeks of exclusive DWR.

The LT test was done with a discontinuous protocol (no citation). Three-minute stages for running, one minute of rest, speed increasing $20.1 \text{ m} \cdot \text{min}^{-1}$. Also, the LT/ VO_2 max tests were done concurrently (based on work by Tanaka et al, 1983). Definition of LT was the nonlinear increase in blood lactate plotted against work rate. This nonlinear rise was found by three separate investigators who were blinded to the order of testing. Pre and post-tests of LT were performed on land only, none in the water.

No significant differences pre and post for VO_2 max, HR max, maximal lactate, LT running velocity, RPE, 5-k TT, or running economy (i.e. VO_2 was the same at specified speeds). The authors do cite articles that show a decrease in VO_2 max in some exclusive DWR experiments, but they feel the intensity was too low in those studies to state it was due to the exclusive water running.

Coyle, E.F. (2005). Improved muscular efficiency displayed as Tour de France champion matures. *Journal of Applied Physiology*, 98, 2191-2196.

For the lactate threshold protocol (cycling), subject pedaled at a constant rpm while increasing workload at 50, 60, 70, 80, and 90% VO_2 max. Stages lasted for five minutes and the protocol was continuous. Blood was either taken via an antecubital vein catheter or by fingertip piercing and examined using the enzymatic spectrophotometric method. LT graph was made comparing LT and VO_2 , then by identifying the VO_2 at which blood lactate increased $1 \text{ mmol} \cdot \text{L}^{-1}$ above baseline values.

The article also anecdotally states that commercially available lactate analyzers give lower maximal lactate concentrations due to the incomplete lysing of red blood cells.

Faude, O., Kindermann, W., & Meyer, T. (2009). Lactate threshold concepts: how valid are they? *Sports Medicine*, 39, 469-490.

This review article identifies many of the inconsistencies between LT tests from different researchers. Through the years, numerous methods have developed as to what the LT really is and arguments have ensued.

One aspect about the LT identified in this review states that blood sample obtained via the earlobe compared to the finger have been statistically lower. As that is the case, we may have lower LT values than are typically seen. However, we will compare the blood lactate curve itself and the samples will be obtained via the earlobe water and land conditions to maintain consistency.

Also mentioned in this review are the disparities that can exist in the visual identification of the LT curve. They state that “it does not seem appropriate to determine this threshold by simple visual inspection.” If there is an objective way to compare land versus water intensities, that would be the best method to determine LT.

Forsyth, J., & Reilly, T. (2005). The combined effect of time of day and menstrual cycle on lactate threshold. *Medicine and Science in Sports and Exercise*, 37, 2046-2053.

In using different methods to determine LT, consideration may need to be given to using female subjects due to the menstrual cycle's effects on LT. These authors found a significantly higher intensity was required to produce a $4.0 \text{ mmol} \cdot \text{L}^{-1}$ during the midluteal phase (6-9 days after ovulation) than for the midfollicular phase (6-9 days after menses). However, they state that using a fixed lactate concentration method (the Dmax method is what they used) is more sensitive to an LT test than a method that uses the shape of the lactate curve. This is due to higher concentrations of estrogen found in the body during the midluteal phase, causing a glycogen-sparing effect and likely causing a decrease in lactate production during sustained exercise. In light of this evidence, using a determination of LT that visually identifies a lactate curve would be appropriate to use a male and female subject population. Using a fixed lactate concentration, only male subjects should be used.

This article did use a continuous protocol, 3-minute stages. Blood was taken from the toe as this was a rowing protocol with more highly trained rowers, rather than running. So a continuous protocol was the most beneficial for them to use to maintain a consistent rhythm of strokes, etc. 36 hours rest between LT sessions was the minimum time waited for this study.

Frangolias, D.D., & Rhodes, E.C. (1995). Maximal and ventilatory threshold responses to treadmill and water immersion running. *Medicine and Science in Sports and Exercise*, 27, 1007-1013.

Using elite distance runners familiar with water immersion running (buoyancy belt worn, suspended WI) effects of WI running and land treadmill running were compared. WI was to the neck and running form best imitated land running as a criterion for inclusion in the study. Lactate measured 30 s and 5 min post- VO_2 max test.

WI had lower RER max values. Lactate concentration at 30 s and 5 min were not statistically different between water and land. Ventilatory threshold points occurred at the same relative percentage of VO_2 max between water and land as well.

Frangolias, D.D., & Rhodes, E.C. (1996). Metabolic responses and mechanisms during water immersion running and exercise. *Sports Medicine*, 22, 38-53.

This is a review article discussing water immersion running and exercise. There are lower VO_2 max values in water immersion compared to land treadmill running. Also, there tends to be lower HR values and higher blood lactate values in water compared to land.

Many of the inconsistencies between land and water in this article are comparable now because of the benefit of the aquatic treadmill. This article is a good review on the discrepancies that once existed between land and water immersion running.

Greene, N.P., Lambert, B.S., Greene, E.S., Carbuhn, A.F., Green, J.S., & Crouse, S.F. (2009). Comparative efficacy of water and land treadmill training for overweight or obese adults. *Medicine and Science in Sports and Exercise*, 41, 1808-1815.

This is one of the first articles to do a training study with the aquatic treadmill compared to land treadmill. Subject population was physically inactive, overweight and obese men and women, college-aged. The study required 12 weeks of exclusive land or water treadmill training three times per week. Weeks one through six entailed increasing intensity from 60% of VO_2 max in 5% of max increments until 85% of max during week six. At that point, VO_2 max was retested and weeks 7-12 entailed exercise intensity at 85% of VO_2 max.

They found that using aquatic treadmills as an exclusive means of training provided a sufficient training stimulus to increase physical fitness. Compared to land treadmill training values, water treadmills provided an equal benefit to this unfit population of subjects.

Greene, N.P., Greene, E.S., Carbuhn, A.F., Green, J.S., & Crouse, S.F. (2011). VO_2 prediction and cardiorespiratory responses during underwater treadmill exercise. *Research Quarterly for Exercise and Sport*, 82, 264-273.

Comparison of submaximal and maximal underwater and land treadmill exercise. Participants were older and less physically active male and females. The overall purpose of this article was two-fold: to determine a VO_2 prediction equation for water treadmill running and to compare submaximal and maximal values land and water treadmill running. Gender did not influence results (i.e. men did not respond differently than women) and maximal efforts land versus water further expand Silvers et al. (2007) to an older less fit population.

Submaximal effort comparisons land and water are essential to the understanding of water treadmill running. Running on land and in water at the same speed elicited significantly lower VO_2 values (except at $80.4 \text{ m}\cdot\text{min}^{-1}$) in water at jets of 0% and 25%.

This article again shows the importance of jets in equalizing metabolic demand on land.

Hall, J., Grant, J., Blake, D., Taylor, G., & Garbutt, G. (2004). Cardiorespiratory responses to underwater treadmill walking in patients with rheumatoid arthritis. *Physiotherapy Research International*, 9, 59-73.

Another article showing VO₂ being lower in water compared to land. This one in particular also showed the benefits of the lower impact in the water for individuals with rheumatoid arthritis. This population was all middle-aged females.

Harrison, R.A., Hillman, M., & Bulstrode, S. (1992). Loading of the lower limb when walking partially immersed: implications for clinical practice. *Physiotherapy*, 78, 164-166.

An older article now but often cited for work performed with unloading of the human body in water at differing depths. The key thing from this article that was needed was the unloading at the xiphoid process, which is 72%. There are a lot of other information relating to buoyancy forces which are critical to understand with water immersion.

Hinghofer-Szalkay, H., Harrison, M.H., & Greenleaf, J.E. (1987). Early fluid and protein shifts in men during water immersion. *European Journal of Applied Physiology*, 56, 673-678.

Another factor to discuss involved with the LT test was correcting for changes in plasma volume and plasma proteins. A study by Hinghofer-Szalkay showed that water immersion for 30 minutes cause an 11% increase in plasma volume in men. Zobel reported statistically different plasma changes on land verses water, but the baseline lactate/plasma readings were taken after the 30 minute period of time of standing to “equilibrate the body chambers.” Based on this information, there is no way to declare that plasma change was due to the exercise itself or from the 30 minute submersion in water prior to exercise.

Howley, E.T., Bassett, D.R., & Welch, H.G. (1995). Criteria for maximal oxygen uptake: review and commentary. *Medicine and Science in Sports and Exercise*, 27, 1292-1300.

This article describes the criteria for a VO_2 max test and the common misconceptions about what makes a maximal oxygen test. The authors concluded after reviewing articles and their criteria used, the plateau in oxygen uptake is sufficient to say it was maximal, so long as the “plateau” is less than 2.1 ml/kg/min or 150 ml/min (based on a 72 kg individual) despite the increase of workload.

To help counteract any questions about the “plateau” in oxygen uptake, researchers use secondary criteria such as blood lactate concentration, maximal heart rate (HR) achieved, and RER. Depending on age range of the subject population, values will change for these secondary criteria. Blood lactate levels range anywhere from 6.7-10.1 mmol \cdot L⁻¹. For the college-aged population, a range of 8-10 mmol \cdot L⁻¹ is appropriate. Maximal HR predictions are commonly used as a criterion in research is not sanctioned by the ACSM as of 1991. With the large margin of error in predicting max HR, using it to specify a maximal test is not an appropriate. It was determined an RQ of 1.15 was the minimum threshold to reach, but the value is still controversial as it ranged from RER of 1.11-1.16.

Overall, if a plateau of oxygen is reached, that should suffice as a maximal oxygen test.

Kilding, A.E., & Jones, A.M. (2005). Validity of a single-visit protocol to estimate the maximum lactate steady state. *Medicine and Science in Sports and Exercise*, 37, 1734-1740.

More of the specifics for the MLSS concept. These authors wanted to investigate whether MLSS could be correctly identified on one visit to the laboratory. There were significant differences in the traditional MLSS method and the one-time lab visit. This will be important as MLSS could be a potential follow up study used between land and water treadmill running.

The traditional determination of MLSS is required. This entails four to five constant load exercise sessions of 30 min each. VO_2 is collected and analyzed to ensure the constant load is met. Blood lactate will be taken frequently during these intervals to find the steady state VO_2 and steady state blood lactate as well.

McArdle, W.D., Katch, F.I., & Katch, V.L. (2010). Exercise Physiology, Nutrition, Energy, and Human Performance, 7th ed. Lippincott Williams & Wilkins, 163-164; 292-294.

Measuring lactate threshold is accomplished in a number of ways. The technique that will be most useful in obtaining samples via finger or ear lobe poke is the blood lactate-exercise VO_2 response. On page 294 of this reference, the authors discuss this method as plotting blood lactate concentrations versus either VO_2 or exercise intensity to see the progression of the lactate values. Then, using a best-fitting straight line will depict the linear portion of the curve in the horizontal and vertical axis and a lactate threshold point can be determined where the two lines intersect. They also mention a standard protocol as 3- or 4-minute increments either continuous or discontinuous.

One other definition that they give (pg. 292) for lactate threshold is “the highest oxygen consumption or exercise intensity achieved with less than a $1.0 \text{ mmol}\cdot\text{L}^{-1}$ increase in blood lactate concentration above the pre-exercise level” from Weltmen et al. (1990).

McGehee, J.C., Tanner, C.J., & Houmard, J.A. (2005). A comparison of methods for estimating the lactate threshold. *Journal of Strength and Conditioning Research*, 19, 553-558.

The main purpose of this study was two-fold: to examine different methods of analysis for determining the lactate threshold and to examine which lactate threshold estimates are the most useful and accurate at predicting LT. The methods used to examine the LT itself were 1) visual identification, 2) $\text{LT}_{D_{\max}}$ which connects a line from the beginning and end lactate values; the point of the line furthest from the curve is fixed with a perpendicular line to show the LT, 3) the $\text{LT}_{\Delta 1}$ which is the point that blood lactate is $1 \text{ mmol}\cdot\text{L}^{-1}$ above baseline values, and 4) $\text{LT}_{4.0}$ which is a fixed $4.0 \text{ mmol}\cdot\text{L}^{-1}$.

The methods were particularly useful in this study as well. They used 4-minute stages on a land treadmill set at a fixed 1% grade. Starting speed varied according to fitness level of the individual and was thereafter raised 0.5 mph ($0.22 \text{ m}\cdot\text{s}^{-1}$). Lactate was analyzed in duplicate by a hand analyzer via fingertip prick. LT curve was identified using blood lactate concentration versus running velocity (i.e. an increase in work rate).

Results showed that the $\text{LT}_{4.0}$ had statistically higher VO_2 , HR, running velocity, percentage of VO_2 peak, and blood lactate concentration than all other methods. The other three methods used were not statistically different from one another. The LT visual had slightly lower LT values, but not statistically significant. This article is in opposition of the recommendation given by Faude et al. (2009) that says an LT visual identification should not be used.

Reilly, T., Dowzer, C.N., & Cable, N.T. (2003). The physiology of deep-water running. *Journal of Sports Sciences*, 21, 959-972.

Lower impact forces exist in water. Water running is used as a supplement of running to reduce miles of stress on land. Hydrostatic pressure causes changes in the blood volume compartments in the body. The level of depth of the water will increase the amount of hydrostatic pressure on the body, which will alter the effect of blood pressure and particularly the stroke volume and cardiovascular responses.

A 3-9% reduction in vital capacity of the lungs has been reported at depths of water at the xiphoid process, being attributed to the rise of the diaphragm and the increase in intrapulmonary blood volume. This explains why the minute ventilation, rates of breathing, etc. would be different land and water.

Rife, R.K., Myrer, J.W., Feland, V.J.B., Hunter, I., & Fellingham, G.W. (2010). Water treadmill parameters needed to obtain land treadmill intensities in runners. *Medicine and Science in Sports and Exercise*, 42, 733-738.

Three methods of training were compared – water treadmill (WTR) barefoot, WTR with shoes, and land treadmill (LTR). Exercise sessions required subjects to exercise at 50%, 60%, 70% and 80% of their VO_2 max for at least five minutes while metabolic data was recorded and analyzed. The authors overall conclusion was that WTR with shoes caused the highest metabolic demand, showing a higher VO_2 and HR overall. Then, the WTR barefoot was significantly higher than LTR in VO_2 and HR for the same intensity of running. With the HR at 150 bpm, VO_2 was significantly less running on LTR compared to WTR. However, at 150 bpm, the WTR with and without shoes were nearly identical (no statistical difference).

The authors state that “the most practical way to induce similar metabolic demands of running on a water treadmill to that of running on a land treadmill is by monitoring HR.” They suggest choosing a WTR speed that will result in a 7 bpm lower HR than it would on LTR for the same metabolic demand. This will show that any relationship between land and water lactate threshold will allow us to determine an appropriate water training intensity to accurately match a land LT test.

There is also a discussion about HR between males and females, likely due to the buoyancy effect in the water treadmill. Overall, women had a higher HR than men. The authors justify that this is due to a higher overall percentage of VO_2 max in women than men at a relative VO_2 , allowing a higher HR.

Rutledge, E., Silvers, W.M., Browder, K., & Dolny D. (2007). Metabolic-cost comparison of submaximal land and aquatic treadmill exercise. *International Journal of Aquatic Research and Education*, 1, 131-146.

This article compares submaximal efforts in the aquatic treadmill versus land treadmill. There were three speeds used in the aquatic setting with three different jet settings (0%, 50%, and 75%). Land treadmill speeds were used to determine comparable metabolic demands as measured by VO_2 . In other words, the VO_2 in water was matched by finding a similar speed on land.

The critical part of this article shows that by adding jet resistance in the water, you can minimize how fast an individual may need to run on land. We will be able to use these submaximal values recorded to find comparable work increases for the LT tests land versus water. We know that at the same speed land versus water there are different HR and VO_2 values given, so we assume blood lactate may be different as well. However, with correction factors of jet and speed in the water, similar work rates can be determined to obtain the same physiological demand land versus water.

Shono, T., Fujishima, K., Hotta, N., Ogaki, T., Ueda, T., Otoki, K., Teramoto, K., & Shimizu, T. (2000). Physiological responses and RPE during underwater treadmill walking in women of middle and advanced age. *Journal of Physiological anthropology and Applied Human Science*, 19, 195-200.

This article will not directly relate to our subject population, but some of their testing techniques are great references. Four minute consecutive stages were used at 20, 30, 40, and 50 meters/min. There was a one minute rest period between bouts, during which time RPE and blood lactate values were obtained. Lactate was measured via the earlobe. Subjects were instructed to maintain the same form across all speeds (arm swing, etc.). Water depth was set at the xiphoid process. Blood lactate measures were only significantly higher when subjects proceeded to the highest speed of $50 \text{ m} \cdot \text{min}^{-1}$ ($2.4 \pm 0.7 \text{ mmol} \cdot \text{L}^{-1}$ vs. $1.1 \pm 0.2 \text{ mmol} \cdot \text{L}^{-1}$ at $40 \text{ m} \cdot \text{min}^{-1}$).

Heart rate and RPE increased in linear fashion, showing that with each increase in perceived exertion, the HR was increasing along with energy expenditure, etc. The energy expenditure was not significantly different among their age groups (50's and 60's).

Silvers, W.M., Rutledge, E.R., & Dolny, D.G. (2007). Peak cardiorespiratory responses during aquatic and land treadmill exercise. *Medicine and Science in Sports and Exercise*, 39, 969-975.

The key differences between DWR and land-based running are clearly defined in the introduction in terms of lower extremity muscle recruitment and kinematics. SWR is also discussed as the alternative to DWR.

The protocol for the VO_2 max tests were to increase speed $13.4 \text{ m} \cdot \text{min}^{-1}$ for 4-5 minutes, then increase incline 2% every minute on land treadmill and increase jet resistance 10% every minute in the aquatic treadmill. Water depth was set at the xiphoid process for aquatic treadmills.

There was no statistical difference between VO_2 max, HR, peak blood lactate, RER, RPE, test time, or final speed on the land treadmill opposed to the aquatic treadmill. Therefore, methods for comparing land and aquatic treadmills will not need to include a VO_2 max test on both land and aquatic treadmills. Other articles (Table 4) shows water depth variations to VO_2 and HR variables that are addressed by the authors in the discussion.

Stainsby, W. N., & Brooks, G.A. (1990). Control of lactic acid metabolism in contracting muscles and during exercise. *Exercise and Sport Science Reviews*, 18, 29-64.

Written by Wendell Stainsby and George Brooks in 1990, this is one of the preeminent articles of authority on the concept and physiology of the lactate threshold. Each of these authors have performed extensive work and research on the topic of lactate threshold, especially at the cellular level to determine the production and clearance of lactate as well as the fates of lactate. Many ideas can be gained from this article that could perhaps elucidate why changes may occur in the LT in water versus land.

One important concept to consider is what the hydrostatic pressure from the water may cause in regards to interstitial fluid shifts or blood osmolality or blood flow to the muscles. Each of these concepts is discussed in this article that could bring insight into the LT test in water especially. With a basic understanding of the LT in water, perhaps we can then relate the new information to this review article.

In regards to blood flow regulation, added pressure in the water could cause changes to blood flow to working skeletal muscle. This concept is closely related to changes in VO_2 as changes in blood flow will alter the amount of O_2 available to the working muscle. This concept could be influential on the production of lactate due to the changes in metabolites for work.

Svedenhag, J., & Seger, J. (1992). Running on land and in water: comparative exercise physiology. *Medicine and Science in Sports and Exercise*, 24, 1155-1160.

One of the primary concepts in this article was to show how VO_2 max values have changed from deep water running (this article) to the current modality of aquatic treadmill running (Silvers et al., 2007). During deep water running these authors performed a lactate threshold test and showed that there were higher blood lactate values at similar VO_2 values and that the LT curve itself occurred earlier in water than on land treadmill running.

Due to the ability to run on the aquatic treadmill and the similar metabolic demands that can be met, the changes in lactate threshold need to be identified as well. This is a good article to support the purpose of this study.

Town, G.P., & Bradley, S.S. (1991). Maximal metabolic responses of deep and shallow water running in trained runners. *Medicine and Science in Sports and Exercise*, 23, 238-241.

There is a strong emphasis in this article that shallow water running is the best way to imitate land running because of the ground contact that is enabled in shallow water. There were no statistical differences between RER and blood lactate values land versus shallow water running. However, blood lactate values in water were still 81% of land values. While these were not statistically different, there is still a large difference between the two modes. Again, with the advent of the aquatic treadmill, it enables running mechanics in water similar to land, which changes the metabolic demands. There is a justification in this article, similar to the Svedenhag and Seger article, to see how the LT changes with water and land treadmill comparisons.

Weltman, A, Snead, D., Stein, P., Seip, R., Schurrer, R., Rutt, R., & Weltman, J. (1990). Reliability and validity of a continuous incremental treadmill protocol for the determination of lactate threshold, fixed blood lactate concentrations, and VO_2max . *International Journal of Sports Medicine*, 11, 26-32.

This article shows that a discontinuous protocol for determining LT gives statistically higher VO_2 values at $2.0 \text{ mmol}\cdot\text{L}^{-1}$. Also, the investigators combined LT/ VO_2 max tests to see if those values could be identified accurately. The LT/ VO_2 max test caused there to be a statistically lower VO_2 max indicating a combined LT/ VO_2 max test was not optimal. The reason for the decreased VO_2 max was the length of the test. It was difficult for the subjects to push themselves to volitional exhaustion after having already exercised for 20-30 minutes performing the LT test.

Zderic, T.W., Coggan, A.R., & Ruby, B.C. (2001). Glucose kinetics and substrate oxidation during exercise in the follicular and luteal phases. *Journal of Applied Physiology*, 90, 447-453.

In connection to Forsyth & Reilly (2003), Zderic et al found a lower lactate concentration at 90% of LT in cycling for 25 minutes for women in the luteal phase when compared to the follicular phase. If women participate in this study, all lactate threshold tests should be conducted during the same phase of the menstrual cycle. VO_2 max tests can be performed at any time as no articles indicate changes in VO_2 max with menstrual cycle. However, when performing the two LT tests, they should remain within the same menstrual phase to try to account for any lactate differences that may result due to hormone changes during submaximal exercise tests. The first LT test could begin 3-4 days after ovulation or menses, followed by the second test at least 36 hours after the previous test. This would reduce hormonal differences between LT tests. They also found no differences between LT tests at different time of day.

Zobell, S.J. (2009). *Lactate threshold: the comparison of running on a land treadmill versus head-out water immersion treadmill running* (Unpublished master's thesis). Brigham Young University, Provo, UT.

Test hypothesis how head-out treadmill water running is compared to land treadmill. 11 subjects total, all males. The LT test on land was performed in 3-minute stages, blood sampled via catheter gauge last minute of each stage. The test started by walking 4 min at flat grade at 3.5 mph, then jogging at a pace that represented 40% of their VO_2 peak. Speed increased from this point 0.5 mph every 3 min until 90% of VO_2 peak was reached (as they didn't know lactate concentrations, this was necessary).

LT tests in water or on land required the subject to stand for 30 minutes to "allow equilibration of body water components before resting blood samples were taken." The LT test in water started with 0% jets and speed increased in the same fashion as the land test, walking 3.5 mph, then 40% of VO_2 peak. Refer to Hinghofer-Szalkay (1987) for more information.

Whole blood was centrifuged and plasma lactate was analyzed with a YSI 3200 lactate analyzer. Lactate concentrations were expressed in $\text{mmol}\cdot\text{kgH}_2\text{O}^{-1}$ after correcting for plasma solid concentration. LT was determined using a log-log plotting of lactate concentrations and oxygen consumption. Least squares linear regression was used to define linearity. The intersection of the two linear lines defined the LT. All values for LT were then described as compared to VO_2 , land versus water.