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Core Stabilization Exercises Enhance Lactate Clearance Following High-Intensity Exercise

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Abstract. Navalta, J.W., and S.P. Hrncir Jr. Core stabilization exercises enhance lactate clearance following high-intensity exercise. *J. Strength Cond. Res. 21(4):1305–1309. 2007.*—Dynamic activities such as running, cycling, and swimming have been shown to effectively reduce lactate in the postexercise period. It is unknown whether core stabilization exercises performed following an intense bout would exhibit a similar effect. Therefore, this study was designed to assess the extent of the lactate response with core stabilization exercises following high-intensity anaerobic exercise. Subjects (N = 12) reported twice for testing, and on both occasions baseline lactate was obtained after 5 minutes of seated rest. Subjects then performed a 30-second Wingate anaerobic cycle test, immediately followed by a blood lactate sample. In the 5-minute postexercise period, subjects either rested quietly or performed core stabilization exercises. A final blood lactate sample was obtained following the 5-minute intervention period. Analysis revealed a significant interaction (p = 0.05). Lactate values were similar at rest (core = 1.4 ± 0.1, rest = 1.7 ± 0.2 mmol·L^{-1}) and immediately after exercise (core = 4.9 ± 0.6, rest = 5.4 ± 0.4 mmol·L^{-1}). However, core stabilization exercises performed during the 5-minute postexercise period reduced lactate values when compared to rest (5.9 ± 0.6 vs. 7.6 ± 0.8 mmol·L^{-1}). The results of this study show that performing core stabilization exercises during a recovery period significantly reduces lactate values. The reduction in lactate may be due to removal via increased blood flow or enhanced uptake into the core musculature. Incorporation of core stability exercises into a cool-down period following muscular work may result in benefits to both lactate clearance as well as enhanced postural control.

Key Words. lactic acid, trunk, lumbo-pelvic-hip complex

Introduction

It is well known that exercise at intensities above the anaerobic threshold results in the accumulation of lactic acid (1, 23). Lactate that has been accumulated during exercise is cleared primarily by muscle tissue. Hermansen and Vaage reported that glycogen synthesis at this site may be the primary mechanism for lactate removal (16), while Åstrand et al. confirmed that approximately 50% of the lactate formed during intense exercise is converted into glycogen in the muscle during recovery (2). It is important to note, however, that lactate is related only to acid-base disruptions and acidity and is a consequence of working muscle rather than the cause of acidosis (28). Indeed, the formation of lactate serves as an important physiological buffer that protects the muscle cell against metabolic acidosis and allows high-intensity exercise to be extended for a period of time (28). Since muscle acidosis has been shown to inhibit oxidative phosphorylation (18), clearance of protons is important for continued muscular work.

It has been established that an active recovery following exercise serves to significantly reduce lactate and associated protons in the postexercise period compared to rest (4, 5, 6, 29). Various modes of recovery exercise have been shown to decrease the lactate accumulated during exercise. Denadai et al. found that running or swimming as recovery modes significantly reduced lactate compared to passive recovery after high-intensity exercise (9). Bonen and Belcastro observed greater decreases in lactate values when subjects performed continuous jogging or intermittent jogging compared to a passive recovery (7). McLellan and Skinner found that lactate removal was enhanced following cycle exercise when recovery was carried out just below the aerobic threshold (22), and Monedero and Donne reported that recovery consisting of both cycling and massage was effective in reducing lactic acid buildup following a maximal effort exercise test (24).

The core musculature is considered to be all the muscles that have an attachment at the lumbo-pelvic-hip (LPH) complex. Training of these muscles typically follows a progression from core stability (i.e., the ability to maintain posture during an exercise) to core strength (i.e., improvement in functional contractility of the musculature) to core power exercises (i.e., the ability of the core musculature to produce force that is transferred to other parts of the body during explosive movement). As a foundation, core training exercises involve little joint motion and are designed primarily to improve intrinsic stabilization of the LPH complex before core strength or power exercises are considered in a training program. Increased ability to stabilize the LPH complex is thought to increase the performance of various athletic and sport-related skills. Although core stability programs have failed to show performance benefits in the limited literature to date (32, 33), programs have been successful when aimed at decreasing low back pain or enhancing trunk musculature (8, 19, 25). In addition, strength and conditioning coaches from all of the major professional sports in this country have ranked core exercises among the top 5 most important exercises for the training of their athletes (10–12, 31).

Active recovery typically involves some form of whole-body exercise that allows muscles to metabolize lactate and thereby facilitates quicker removal compared to a resting recovery (4). It is unknown whether exercises involving little joint movement directed at the core musculature of the LPH complex would also significantly decrease lactic acid buildup in the postexercise period. Therefore, the purpose of this study was to assess the lactate response to core stabilization exercises following high-intensity anaerobic exercise.

Methods

Experimental Approach to the Problem

To examine what effect activation of the core musculature had on lactate clearance, a controlled laboratory experi-

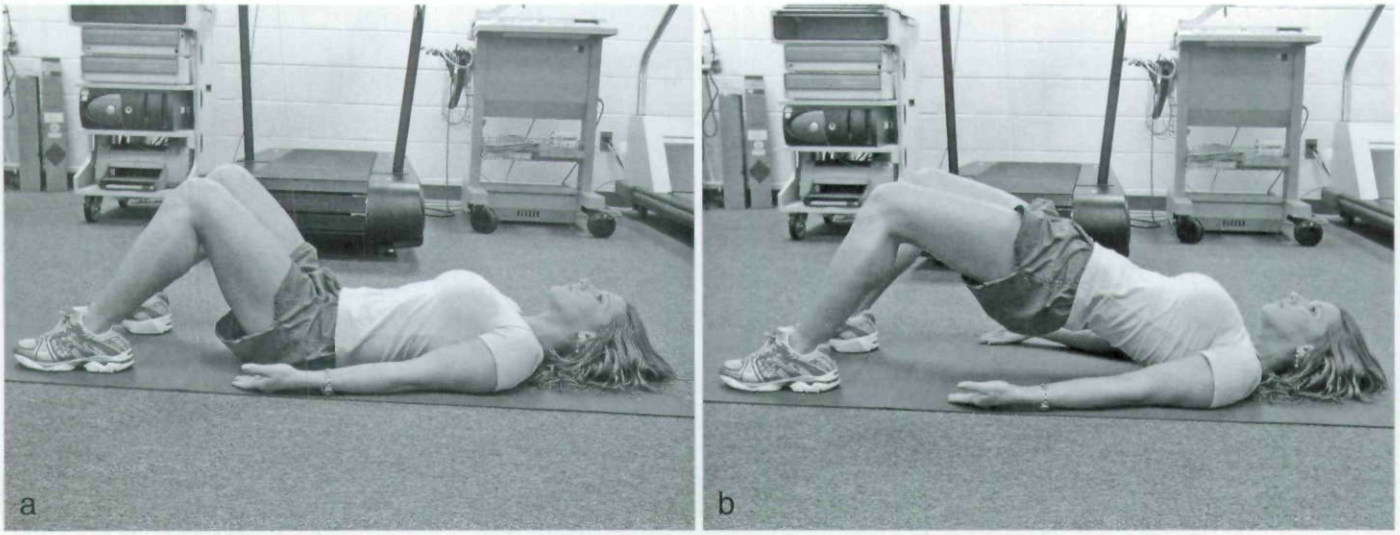

FIGURE 1. Core stabilization exercise 1: supine position with knees bent followed by elevation of the hips. Consists of 2-second concentric phase, 2-second isometric phase, and 4-second eccentric phase.

ment was conducted. Male and female subjects performed a 30-second Wingate anaerobic test to facilitate a rise in lactate concentration, followed by a 5-minute intervention of either quiet rest or core stabilization exercises. Lactate measurements were taken at baseline, immediately after the Wingate anaerobic test, and following the 5-minute postexercise intervention period, which was counterbalanced among subjects.

Following the construct that core exercise programs progress from stability to strength and then to power, the chosen activities in this study were classified as core stability exercises. Specifically, these exercises involved little joint movement while focusing on the intrinsic core musculature to stabilize itself prior to or during movement. Core stability exercises were chosen for this study rather than strength or power exercises because these exercises are done initially in core training programs. In addition, all subjects in the present study had the ability to perform core stability exercises while maintaining proper posture, whereas core strength or power exercises should be executed by individuals with developed core musculature who can functionally perform the exercises. Finally, core strength and power exercises are typically performed at higher intensities than core stability exercises, and the consequences of these exercises to terms of lactate production was unknown.

Subjects

Twelve healthy subjects (n = 7 male, n = 5 female) volunteered to participate in the study. The mean age of subjects participating was 22 ± 1 (*SE*) years, height was 170 ± 3 cm, and weight was 85 ± 6 kg. All subjects were active (exercise >3 days per week) and included both individuals who were not involved in collegiate athletics (female = 2, male = 3) and those who were (female = 3 softball; male = 1 football, 1 baseball, 2 basketball). Previous to participation, subjects provided written informed consent that was approved by the university Human Subjects Committee.

Procedures

Participants reported to the Kinesiology Laboratory on 2 occasions separated by at least 3 days. On both occasions, resting blood lactate measurements were obtained via finger stick using universal precautions following 5–10 minutes of quiet sitting. Lactate concentrations were determined with the use of an Accutrend Lactate analyzer (Roche Diagnostics, Mannheim, Germany). Approximately 20–25 μl of whole blood were applied to a test strip that had been inserted into the analyzer. Once a blood sample had been applied to the test strip, lactate was measured via enzymatic determination and reflectance photometry at 660-nm wavelength for 60 seconds.

After resting measurements were obtained, participants were asked to perform the Wingate anaerobic power test on a cycle ergometer (Monarch, Stockholm, Sweden). The workload for males was determined by multiplying body weight by 0.085 and for females multiplying body weight by 0.075. A finger-stick blood sample was obtained immediately following the all-out 30-second cycle bout and again at 5 minutes postexercise.

Recovery

After the 30-second bout of exercise, subjects received instructions regarding the postexercise period. On one occasion, participants were instructed to sit quietly during the postexercise period. On the other occasion, participants performed core stabilization exercises. The order of recovery type performed during the postexercise period was counterbalanced among subjects. Exercises included the following.

Exercise 1. The subject began lying supine with palms in the anatomical position and the knees bent at approximately 90°. From this initial position, the subject posteriorly rotated the pelvis and elevated the hips while the shoulders remained on the ground (Figure 1). The concentric "pushing up" phase was completed in 2 seconds, and the subject held the position at the top in the isometric phase for 2 seconds and completed the eccentric lowering phase in 4 seconds.

Exercise 2. Initial position was lying on the floor prone with the arms in front of the body. Subjects then externally rotated, retracted, and depressed the shoulder girdle while lifting the chest slightly off of the ground (Figure 2). The concentric phase was completed in 2 seconds, the isometric phase was held for 2 seconds, and the eccentric lowering phase was completed in 4 seconds.

Exercise 3. The subject assumed a prone position on

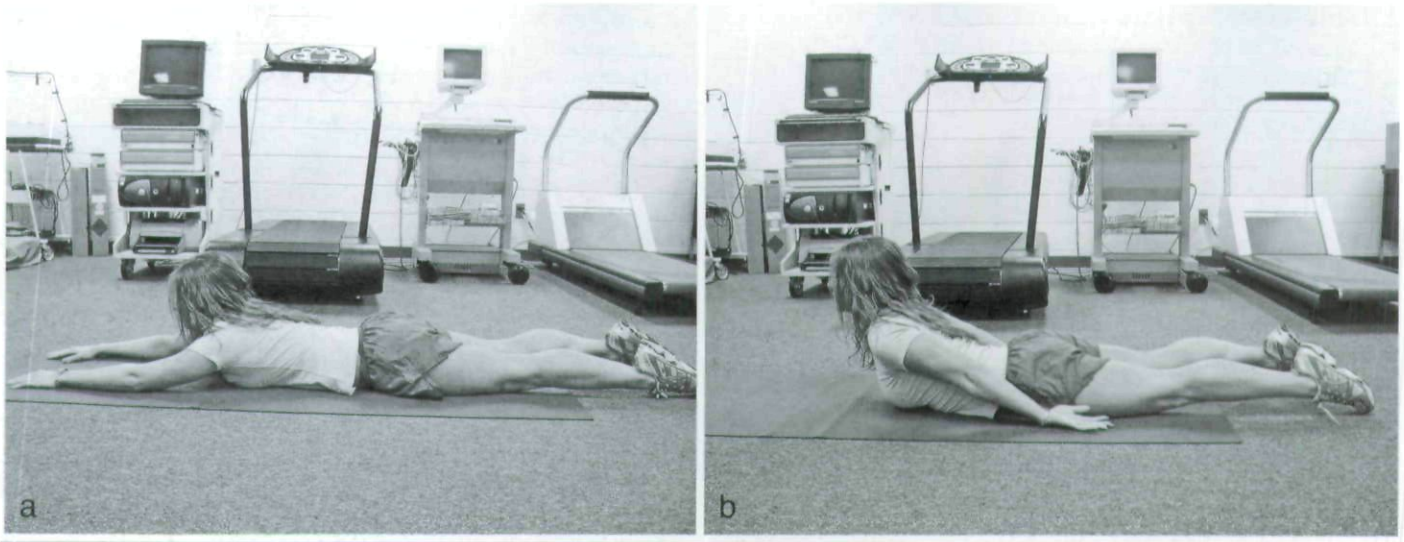

FIGURE 2. Core stabilization exercise 2: prone position with the arms in front of the body followed by external rotation, retraction, and depression the shoulder girdle while lifting the chest off of the ground. Consists of 2-second concentric phase, 2-second isometric phase, and 4-second eccentric phase.

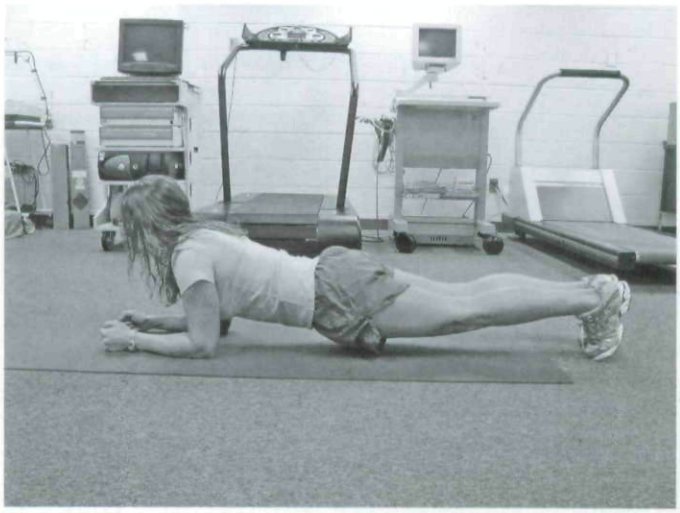

FIGURE 3. Core stabilization exercise 3: prone position on forearms and toes. Position maintained for 8 seconds.

the forearms and toes that was maintained for 8 seconds (Figure 3).

Statistical Analyses

Statistical analyses were carried out using Statistica 5.1 (Statsoft Inc., Tulsa, OK). Anaerobic power data were analyzed using *t*-tests for dependent samples. Lactate data was analyzed using a 2 (gender) × 2 (recovery type) × 3 (condition) repeated-measures analysis of variance with significance accepted at the $p \leq 0.05$ level. Tukey's HSD post hoc analysis was performed to determine conditions that were statistically different from one another. Data were also compared using Pearson product-moment correlation coefficients.

RESULTS

Analysis revealed a significant interaction between recovery intervention and condition ($p = 0.009$). Lactate values were similar at baseline (core = 1.4 ± 0.1 mmol·L^{-1}, rest = 1.7 ± 0.2 mmol·L^{-1}) and immediately after exercise (core = 4.9 ± 0.6 mmol·L^{-1}, rest = 5.4 ± 0.4 mmol·L^{-1}).

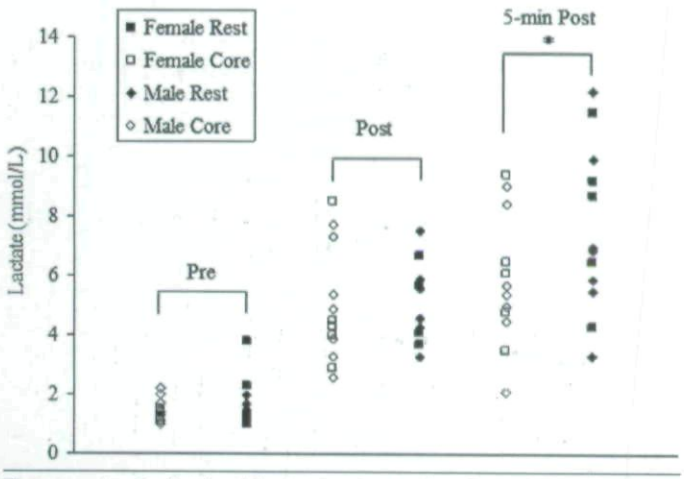

FIGURE 4. Individual lactate values of male and female subjects ($N = 12$) before (Pre), immediately after a 30-second Wingate anaerobic test (Post), and following a postexercise intervention (5 minutes Post). Closed symbols represent lactate values during the trial in which subjects sat quietly during the postexercise period, whereas open symbols represent lactate values during the trial in which core stabilization exercises were performed in the postexercise period. An asterisk (*) indicates significant difference between interventions ($p = 0.05$).

However, core stabilization exercises performed during the 5-minute postexercise period significantly reduced lactate values when compared to rest (5.9 ± 0.6 mmol·L^{-1} vs. 7.6 ± 0.8 mmol·L^{-1}, $p = 0.05$; Figure 4). While main effects were evident for recovery intervention ($p < 0.0001$) and condition ($p = 0.002$), the effect of gender was not significant ($p = 0.877$).

Results of the Wingate anaerobic cycle tests are reported in Table 1. The peak power output ($p = 0.5108$) and average anaerobic capacity ($p = 0.3691$) measures were not significantly different between trials in which either rest or core exercises were performed during the 5-minute postintervention. However, subjects displayed a significant decline in power during performance of the Wingate test in which core exercises were to be completed in the posttest intervention compared to rest ($p = 0.0478$).

There was not a significant relationship between Win-

TABLE 1. Anaerobic measures of subjects ($N = 12$) who completed the Wingate anaerobic power test in which the 5-minute postintervention was rest (rest trial) or core exercise (core trial). Values are mean ± *SE*. An asterisk (*) indicates significant difference between trials ($p < 0.05$).

	Anaerobic capacity (W)	Peak power (W)	Power decline (%)
Rest trial	479 ± 30	559 ± 38	29 ± 2
Core trial	466 ± 29	574 ± 39	36 ± 3*

gate peak power and lactate concentration 5 minutes following the test ($r = 0.3460$, $r^2 = 0.1197$, $p = 0.0977$). However, Wingate anaerobic power and lactate following the 5-minute intervention was significantly correlated ($r = 0.4168$, $r^2 = 0.1737$, $p = 0.0428$).

DISCUSSION

In exercising muscle, the formation of lactate serves as a physiological buffer to protect the cell against metabolic acidosis by acting as a proton acceptor (28). In this respect, it is important to note that lactate measures are a consequence of working muscle rather than the cause of acidosis (28). Blood lactate concentration in this context represents the net total of lactate production versus clearance. At higher levels of intensity, clearance is important because accumulated protons and muscle acidosis have been shown to inhibit oxidative phosphorylation (18). The results reported here indicate that activation of the core stabilization muscles during a 5-minute recovery period significantly decreases the concentration of lactate measured in the venous blood when compared with rest. Although the present study was not designed to determine mechanisms of lactate clearance, a number of possible explanations exist.

The first explanation for reduced lactate concentration following high-intensity exercise may be an increase in blood flow to active muscles and subsequent metabolism. However, in a study performed on canine gastrocnemius muscle, Gladden et al. found that increased blood flow 165% above normal did not have a significant effect on lactate uptake (14). Although blood flow rates were not measured in the current study, it is unlikely that the core stabilization exercises performed increased blood flow to a significant extent to facilitate lactate removal. The more likely explanation for the increased clearance of lactate seen in the present study during the core exercise intervention relates to muscle fiber type. Although muscle fiber types vary greatly between individuals, a number of investigators have found that the core musculature has a predominance of type I and type IIa fibers, which is consistent with the role of these muscles in maintaining posture (15, 20, 26). It is known that these fiber types take up lactate quicker (i.e., at lower concentrations) (27) and have a greater capacity to oxidize lactate compared with glycolytic type IIx muscle fibers (3). Given the oxidative nature of the core muscles and their role in maintaining posture, it is possible that the activation of these muscles following high-intensity exercise facilitates lactate disposal during recovery.

In the present study, the core exercise intervention decreased lactate concentration 22.4% compared to rest. Although the comparison of core exercise with other interventions that successfully reduce lactate following exercise is difficult because of varying protocols used to elevate lactate and the timing of blood sampling following muscular work, selected studies will be presented. After high-intensity cycling, 10 minutes of low-intensity cycle recovery reduced arterial lactate by 13.33% versus passive recovery (4). Denadai et al. used both running and swimming to elevate lactate concentrations and observed lactate values after 1 minute of a passive recovery, swimming recovery, or running recovery (9). Running recovery reduced lactate by 11.25% following swimming and 7.14% following running, while swimming recovery decreased lactate by 12.5% after swimming and 1.19% following running (9). Lactate concentrations 5 minutes following a 1-mile run were not different among various recovery interventions; however, 10 minutes after the bout, intermittent jogging reduced lactate by 14.93%, and continuous jogging decreased values by 34.19% compared to rest (7).

Previous studies incorporating core stability training programs have failed to show improvement in performance measures (32, 33). Stanton et al. trained subjects 2 times per week for 6 weeks using Swiss ball training, with each session lasting approximately 25 minutes (32). While core stability increased, there was no effect on $\dot{V}O_2$max, running economy, or running posture (32). Tse et al. trained subjects twice per week for 8 weeks, with each session lasting between 30 and 40 minutes (33). While core strength increased with this training protocol, no improvement was observed during the performance of a 2,000-m maximal rowing ergometer test (33). The lack of core stability training to affect performance variables seems discouraging given the fact that many strength and conditioning professionals consider core exercises an important part of their programming (10–12, 31). Perhaps the discrepancy lies not in the core stability training programs but in the performance variables being tested by investigators. In the present study, we found that performing core stability exercises following high-intensity exercise effectively reduces lactate concentration. Exercise training has been shown to eliminate lactate up to 35% faster following an 8-week program (29). Core stability programs may have an effect on performance variables associated with the buildup of lactate, such as submaximal endurance exercise below the lactate threshold or repeated exercise bouts in which lactate clearance would confer an advantage. The assessment of core stability training on these types of performance variables warrants further investigation.

It should be noted that lactate values observed in the present study are somewhat lower than has previously been reported in subjects following the Wingate anaerobic cycle test (20, 30). While the Wingate anaerobic test was used in the present study merely to induce increases in concentration rather than maximal lactate values, various explanations exist to explain the lower measures when compared to other studies. The most likely reason for low lactate values in the present study is that only modest power output was obtained during the Wingate test. However, the subjects of Jordan et al. produced peak power output more than double compared to the present study, yet lactate measures were similar ranging from 7.86–9.07 $mmol \cdot L^{-1}$ (17). The timing of blood sampling after exercise also affects lactate measurement, as lactate must diffuse from the muscle compartment into the blood. A common practice is to take blood lactate measures at 3 minutes following muscular work (13, 17). Investigators wishing to obtain peak lactate concentrations have drawn samples at 3, 5, 7, 9, and 11 minutes postexercise (30) or had subjects complete 3 successive Wingate cycle tests

(21). In the present study, a 5-minute postexercise sample was chosen to allow subjects time in which to perform the core stability exercises.

PRACTICAL APPLICATIONS

A variety of interventions have shown that dynamic exercise is successful in reducing lactate concentration following intense work. The present study shows for the first time that performing core exercises also has the ability to reduce lactate in the postexercise period. Based on the results of this study, core stability exercises performed during a cool-down period following activity would help facilitate lactate clearance in addition to the positive postural effects associated with core training. As such, core stability training incorporated into the cool-down period may be warranted. Although further research is needed, it is possible that core stability training, which focuses on type I and IIa muscle fibers of the trunk, could further enhance lactate removal during or following muscular work. The practical application for endurance athletes or athletes who perform repetitive high-intensity bouts during competition should be an increased lactate threshold or an enhanced ability to clear lactate between bouts. In addition, athletes who have time between training drills could perform core stability exercises for the dual benefit of reducing lactate levels and enhancing the core musculature. Finally, core stability training in special populations with functional limitations would result not only in better postural control for these individuals but also in the ability to carry out work at higher functional capacities and for longer amounts of time before lactate buildup begins to inhibit muscular activity.

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