CHAPTER-II

Review of Related Literature

A review of literature that the research scholar could gather in library of the Lakshmibai Institute of Physical Education, Gwalior given in this chapter.

The purpose of this study was to examine the effects of fatigue on biomechanical indices of soccer kick performance. Ten male amateur soccer players performed maximal instep kicks prior to, in the middle and after the implementation of a 90 min intermittent exercise protocol. Three-dimensional data, ground reaction forces (GRFs) and segmental moments were measured during the kick while blood lactate and ammonia concentrations were monitored throughout the protocol. Analysis of variance designs with repeated measures indicated a significant increase in ammonia (P<0.01) and lactate levels (P<0.01) following fatigue. The GRFs and joint displacement curves during the kick remained unaltered after fatigue (P>0.01). However, post-fatigue maximum angular velocity of the shank, the net moments acting on the shank and the resultant joint moments were significantly lower compared with the corresponding pre-exercise values (P<0.01). The velocity of the ball was 24.69 m/s prior to the protocol and significantly decreased to

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21.78 m/s after (P<0.01). Similarly, the ball/foot speed ratio significantly (P<0.01) declined from 1.40+/-.12 (pre-fatigue) to 1.33+/-.0.18 (post-fatigue). The present results suggest that an exercise protocol that simulates soccer game conditions results in significant impairment of soccer kick performance. This could be attributed to alterations of the function of the neuromuscular system and force generation capacity, which may have altered the mechanics of soccer kick performance.

To examine the physiological response, reliability, and validity of the Yo-Yo intermittent recovery level 2 test (Yo-Yo IR2). Thirteen normally trained male subjects carried out four Yo-Yo IR2 tests, an incremental treadmill test (ITT), and various sprint tests. Muscle biopsies and blood samples were obtained, and heart rate was measured before, during, and after the Yo-Yo IR2 test. Additionally, 119 Scandinavian elite soccer players carried out the Yo-Yo IR2 test on two to four occasions. Yo-Yo IR2 performance was 591 +/- 43 (320-920) m or 4.3 (2.6-7.9) min. Test-retest coefficient of variation in distance covered was 9.6% (N = 29). Heart rate (HR) at exhaustion was 191 +/- 3 bpm, or 98 +/- 1% HRmax. Muscle lactate was 41.7 +/- 5.4 and 68.5 +/- 7.6 mmol x kg(-1) d.w. at 85 and 100% of exhaustion time, respectively, with

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corresponding muscle CP values of 40.4 +/- 5.2 and 29.4 +/- 4.7 mmol x kg(-1) d.w. Peak blood lactate was 13.6 +/- 0.5 mM. Yo-Yo IR2 performance was correlated to ITT performance (r = 0.74, P < 0.05) and VO2max (r = 0.56, P < 0.05) but not to 30- and 50-m sprint performance. Yo-Yo IR2 performance was better (P < 0.05) for international elite soccer players than for moderate elite players (1059 +/- 35 vs 771 +/- 26 m) and better (P < 0.05) for central defenders (N = 21), fullbacks (N = 20), and midfielders (N = 48) than for goalkeepers (N = 6) and attackers (N = 24). Fifteen elite soccer players improved (P < 0.05) Yo-Yo IR2 performance by 42 +/- 8% during 8 wk of preseasonal training. This study demonstrates that the Yo-Yo IR2 test is reproducible and can be used to evaluate an athlete's ability to perform intense intermittent exercise with a high rate of aerobic and anaerobic energy turnover. Specifically, the Yo-Yo IR2 test was shown to be a sensitive tool to differentiate between intermittent exercise performance of soccer players in different seasonal periods and at different competitive levels and playing positions.

The purpose of this study was to examine the running velocities and heart rates at fixed lactate concentrations of young soccer players according to playing position and age. A total of 223 young male soccer

players participated in this study. Each player performed incremental exercise tests on a treadmill. Running velocities and heart rates at 2 mmol/L-1, 2.5 mmol/L-1, 3 mmol/L-1, and 4 mmol/L-1 blood lactate concentrations were calculated with use of the spline function. Data were analyzed through analysis of variance to examine differences among various playing positions (i.e., defenders, midfielders, and forwards) and 3 age groups (U17, under 17 y; U19, under 19 y; and U21, under 21 y). No significant differences were discerned between defenders, midfielders, and forwards in terms of running velocities and heart rates in accordance with specified lactate concentrations. Running velocities corresponding to all lactate concentrations showed no significant differences at all age groups, but heart rates in soccer players in the U21 and U19 age groups were significantly lower than in the U17 age group. Following a 3-y trial of 20 players, running velocities increased and heart rates decreased at all corresponding lactate concentrations. Results of this study suggest that (1) the endurance performance level of young soccer players is similar for all positions, and (2) heart rates are lowered with age and with training.

To examine muscle and blood metabolites during soccer match play and relate it to possible changes in sprint performance. Thirty-one

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Danish fourth division players took part in three friendly games. Blood samples were collected frequently during the game, and muscle biopsies were taken before and after the game as well as immediately after an intense period in each half. The players performed five 30-m sprints interspersed by 25-s recovery periods before the game and immediately after each half (N=11) or after an intense exercise period in each half (N=20). Muscle lactate was 15.9+/−1.9 and 16.9+/−2.3 mmol.kg d.w. during the first and second halves, respectively, with blood lactate being 6.0+/−0.4 and 5.0+/−0.4 mM, respectively. Muscle lactate was not correlated with blood lactate (r=0.06−0.25, P>0.05). Muscle glycogen decreased (P<0.05) from 449+/−23 to 255+/−22 mmol.kg d.w. during the game, with 47+/−7% of the muscle fibers being completely or almost empty of glycogen after the game. Blood glucose remained elevated during the game, whereas plasma FFA increased (P<0.05) from 0.45+/−0.05 to 1.37+/−0.23 mM. Mean sprint time was unaltered after the first half, but longer (P<0.05) after the game (2.8+/−0.7%) as well as after intense periods in the first (1.6+/−0.6%) and second halves (3.6+/−0.5%). The decline in sprint performance during the game was not correlated with muscle lactate, muscle pH, or total glycogen content. Sprint performance is reduced both temporarily during a game and at the end of a soccer game. The latter finding may be explained by low glycogen
levels in individual muscle fibers. Blood lactate is a poor indicator of muscle lactate during soccer match play.

The aim of this study was to quantify response to a soccer-specific intermittent (INT) treadmill protocol based on notational analysis of match-play. Ten male semiprofessional football players (age 24.7 +/- 4.4 yr, body mass 77.1 +/- 8.3 kg, VO2max 63.0 +/- 4.8 ml x kg x min(-1)) completed the 90 minute INT protocol and a steady-state (SS) protocol eliciting the same distance covered. Physiological (heart rate [HR], ratings of perceived exertion [RPE], blood lactate concentration, salivary cortisol concentration) and mechanical (electromyography [EMG] of biceps femoris and rectus femoris) responses were obtained at 15 minute intervals throughout each protocol. The physiological and mechanical responses were typically greater during the INT protocol than during the SS protocol, tending to increase as a function of exercise duration. The INT activity profile induces cumulative mechanical load on the musculoskeletal system. The increased incidence of injury toward the latter stages of match-play is attributed to compromised movement mechanics, rather than physiological strain.

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AIM: The purposes of the present study were: 1) to evaluate heart rate and technical-tactical differences, if any, during "6-a-side" drills, played on 2 pitch dimensions (30x40 m and 50x40 m) and duration (3 min and 8 min); 2) to assess the variability of data between repeated experimental sessions; 3) to evaluate training intensities from heart rate at lactate threshold. METHODS: Laboratory measurements of maximal oxygen consumptions, maximum heart rates and lactate thresholds were performed on 9 soccer players who played at Regional level. For test and retest field sessions, the exercise intensities were calculated from heart rate monitoring and match analysis (number of actions, consecutive passes, players involved in a single action) was performed. RESULTS: No significant differences were found in heart rate frequency distributions between test and retest sessions. Statistically significant differences in frequency distributions of heart rate were found only between the 3 min and 8 min drills played on the 40x50 m pitch. Regarding exercise intensity, significant differences (P<0.01) were found for pitch dimension, with higher intensities shown during the 30x40 m pitch trials. When technical data were related to time units, no differences were found among experimental settings. CONCLUSIONS: These data indicate that coaches could better modulate the training intensity by

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varying the pitch dimension, with the smaller individual playing area (30x40 m) having a large impact on the metabolic demands of exercise.

The purpose of this study was to examine the running velocities and heart rates at fixed lactate concentrations of young soccer players according to playing position and age. A total of 223 young male soccer players participated in this study. Each player performed incremental exercise tests on a treadmill. Running velocities and heart rates at 2 mmol/L-1, 2.5 mmol/L-1, 3 mmol/L-1, and 4 mmol/L-1 blood lactate concentrations were calculated with use of the spline function. Data were analyzed through analysis of variance to examine differences among various playing positions (ie, defenders, midfielders, and forwards) and 3 age groups (U17, under 17 y; U19, under 19 y; and U21, under 21 y). No significant differences were discerned between defenders, midfielders, and forwards in terms of running velocities and heart rates in accordance with specified lactate concentrations. Running velocities corresponding to all lactate concentrations showed no significant differences at all age groups, but heart rates in soccer players in the U21 and U19 age groups were significantly lower than in the U17 age group. Following a 3-y trial of 20 players, running velocities increased and heart rates decreased at all corresponding lactate concentrations. Results of this study suggest that

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(1) the endurance performance level of young soccer players is similar for all positions, and (2) heart rates are lowered with age and with training.

Bioenergetic interpretations of energy transfer specify that rapid anaerobic, substrate-level adenosine triphosphate (ATP) turnover with lactate production is not appropriately represented by an oxygen uptake measurement. Two types of weight training, 60% of 1 repetition maximum (1RM) with repetitions to exhaustion and 80% of 1RM with limited repetitions, were compared to determine if blood lactate measurements, as an estimate of rapid substrate-level ATP turnover, provide a significant contribution to the interpretation of total energy expenditure as compared with oxygen uptake methods alone. The measurement of total energy expenditure consisted of blood lactate, exercise oxygen uptake, and a modified excess postexercise oxygen consumption (EPOC); oxygen uptake-only measurements consisted of exercise oxygen uptake and EPOC. When data from male and female subjects were pooled, total energy expenditure was significantly higher for reps to exhaustion (arm curl, +27 kJ; bench press, +27 kJ; leg press, +38 kJ; p < 0.03) and limited reps (arm curl, +12 kJ; bench press, +23 kJ; leg press, +24 kJ; p < 0.05) when a separate measure of blood lactate was part of the interpretation. When the data from men and women were

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8 Scott CB. Contribution of blood lactate to the energy expenditure of weight training. J Strength Cond Res. 2006 May;20(2):404-11
analyzed separately, blood lactate often made a significant contribution to
total energy expenditure for reps to exhaustion (endurance-type training),
but this trend was not always statistically evident for the limited reps
(strength-type training) protocol. It is suggested that the estimation of
total energy expenditure for weight training is improved with the
inclusion, rather than the omission, of an estimate of rapid anaerobic
substrate-level ATP turnover.

The purpose of this study was to compare the physiological results
of 2 incremental graded exercise tests (GXTs) and correlate these results
with a short-distance laboratory cycle time trial (TT). Eleven men (age 25
 +/- 5 years, Vo(2)max 62 +/- 8 ml.kg(-1).min(-1)) randomly underwent 3
laboratory tests performed on a cycle ergometer. The first 2 tests
consisted of a GXT consisting of either 3-minute (GXT(3-min)) or 5-
minute (GXT(5-min)) workload increments. The third test involved 1
laboratory 30-minute TT. The peak power output, lactate threshold, onset
of blood lactate accumulation, and maximum displacement threshold
(Dmax) determined from each GXT was not significantly different and in
agreement when measured from the GXT(3-min) or GXT(5-min). Furthermore, similar correlation coefficients were found among the

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results of each GXT and average power output in the 30-minute cycling TT. Hence, the results of either GXT can be used to predict performance or for training prescription.

This study was undertaken to examine the endurance performance of elite soccer players, according to age and playing position. A total of 197 male soccer players participated in this study. Each player performed exercise tests on the treadmill that included 3-minute runs and 30-second blood sampling intervals. During these tests, running speeds at the first and second stages were 10 km/hr -1 and 12 km/hr -1, respectively. When these tests were completed, running speed was increased by 1 km/hr every 3 minutes until the runner reached exhaustion. Blood samples were analyzed immediately by means of an automated lactate analyzer. Heart rate was monitored continuously at 5-second intervals. Running velocities and heart rates at 2-mmol/L -1, 2.5-mmol/L -1, 3-mmol/L -1, and 4-mmol/L -1 blood lactate concentrations were calculated with use of the spline function. Analysis of variance was used to analyze data to determine the differences between playing positions (goalkeepers, defenders, midfielders, and forwards) and age groups (older than 30 years of age, between 25 and 29 years old, between

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20 and 24 years old, and 19 years old and younger). Statistical significance was set at P<.01. No significant differences were revealed between defenders, midfielders, and forwards regarding running velocities and heart rates and their correlation with specified lactate concentrations. Goalkeepers demonstrated lower endurance performance than players in the other playing positions (P<.001). Running velocities corresponding to all lactate concentrations showed no significant differences in all age groups, but heart rates in soccer players older than 30 years of age were significantly lower than those of players in other age groups (P<.01). Results of this study suggest that the endurance performance level of professional players is similar for players in all positions, except for goalkeepers, and that endurance performance is not adversely affected when a person's age increases beyond 30 years of age.

To examine the changes in aerobic endurance performance of professional youth soccer players throughout the soccer season. METHODS: Nine youth soccer players were tested at six different time points throughout the soccer season by sub-maximal blood lactate assessment, using an incremental treadmill protocol. Whole blood lactate concentration and heart frequency (Hf) were determined at each exercise.

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stage. Running velocities at the first lactate inflection point (v-T(lac)) and at a blood lactate concentration of 4 mmol l(-1) (v-4mM) were determined. RESULTS: Running velocity at the two lactate thresholds increased from the start of pre-season training to the early weeks of the competitive season, from 11.67 (0.29) to 12.96 (0.28) km h(-1) for v-T(lac), and from 13.62 (0.25) to 14.67 (0.24) km h(-1) for v-4mM (p<0.001). However, v-T(lac )and v-4mM when expressed relative to maximum heart frequency (Hf(max)) remained unchanged. The Hf to blood lactate concentration relationship was unchanged after the pre-season training period. The two expressions of lactate threshold did not reveal differences between each other. CONCLUSION: Running velocity at v-T(lac )and v-4mM increased significantly over the pre-season period, but v-T(lac )and v-4mM were unchanged when expressed relative to Hf(max). This finding may indicate that increased endurance performance may be mainly attributable to alterations in Vo(2max). Although lactate assessment of soccer players is useful for determining endurance training adaptations in soccer players, additional assessment of the other two determinants of endurance performance (Vo(2max) and running economy) may provide more useful information for determining physiological adaptations resulting from soccer training and training interventions.
The objective of this study was to analyze the validity of the velocity corresponding to the onset of blood lactate accumulation (OBLA) and critical velocity (CV) to determine the maximal lactate steady state (MLSS) in soccer players. Twelve male soccer players (21.5 +/- 1.0 years) performed an incremental treadmill test for the determination of OBLA. The velocity corresponding to OBLA (3.5 mM of blood lactate) was determined through linear interpolation. The subjects returned to the laboratory on 7 occasions for the determination of MLSS and CV. The MLSS was determined from 5 treadmill runs of up to 30-minute duration and defined as the highest velocity at which blood lactate did not increase by more than 1 mM between minutes 10 and 30 of the constant velocity runs. The CV was determined by 2 maximal running efforts of 1,500 and 3,000 m performed on a 400-m running track. The CV was calculated as the slope of the linear regression of distance run versus time. Analysis of variance revealed no significant differences between OBLA (13.6 +/- 1.4 km.h(-1)) and MLSS (13.1 +/- 1.2 km.h(-1)) and between OBLA and CV (14.4 +/- 1.1 km.h(-1)). The CV was significantly higher than the MLSS. There was a significant correlation between MLSS and OBLA (r = 0.80), MLSS and CV (r = 0.90), and OBLA and CV (r = 0.80). We can conclude that the OBLA can be

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utilized in soccer players to estimate the MLSS. In this group of athletes, however, CV does not represent a sustainable steady-state exercise intensity.

The aerobic capacity of soccer players substantially influences their technical performance and tactical choices. Thus, the assessment of soccer players' aerobic performance should be of interest for soccer coaches in order to evaluate and improve their endurance training sessions. In this study, we present a new test to assess aerobic performance in soccer by means of a specific dribbling track: the Hoff test. We further determined whether improvement in maximal oxygen uptake was reflected in increased distance covered in the Hoff test.

METHODS: We tested 18 male soccer players (14 years old) both in the laboratory and using the Hoff test before and after 8 weeks of soccer training. RESULTS: The distance covered in the Hoff test correlated significantly with maximum oxygen uptake, and improved by 9.6% during the 8 week training period, while maximum oxygen uptake and running economy improved by 12 and 10%, respectively. Backward multiple regression showed maximum oxygen uptake to be the main explanatory variable for the distance covered in the Hoff test.

CONCLUSION: The present study demonstrated a significant correlation between laboratory testing of VO(2max) and performance in the Hoff test. Furthermore, training induced improvements in VO(2max) were reflected in improved performance in the Hoff test. We suggest that it should be a goal for active U-15 soccer players to cover more than 2100 metres in the Hoff test, as this requires a VO(2max) of above 200 ml/kg(0.75)/min, which should serve as a minimum in modern soccer.

The purpose of this investigation was to estimate the physiologic strain on players during various soccer training activities. Ten soccer players from the first division soccer league of Turkey were used as subjects. The heart rate responses were measured during 4 types of soccer training. First, the heart rates that corresponded to a blood lactate concentration of both 2 and 4 mM were measured, and then, during the 4 types of training, they were correlated with the proportion of time that the heart rate was below the 2-mM lactate line, between the 2- and 4-mM lactate lines, and above the 4-mM lactate line. Mean heart rates during friendly match, modified game, tactical training, and technical training activities were 157 +/- 19, 135 +/- 28, 126 +/- 21, and 118 +/- 21 b.min(-1), respectively. The differences between all of these soccer training

14 Eniseler N. Heart rate and blood lactate concentrations as predictors of physiological load on elite soccer players during various soccer training activities. J Strength Cond Res. 2005 Nov;19(4):799-804
activities were statistically significant (p < or = 0.01). The results demonstrate that (a) technical and tactical training consisted of very low exercise intensities (most of the heart rates were below the 4-mM lactate level) and (b) the percentages of time that the heart rate correlated to a point above the 4-mM lactate reference level during the friendly match and modified game were 49.6 +/- 27.1% and 23.9 +/- 24.5%, respectively. The practical implications of these findings are that, by using 2- to 4-mM reference lines, coaches can structure heart rate zones that can help determine the individualized exercise intensity for their players as well as estimate overall exercise intensity during soccer training.

The purpose of this investigation was to study effects of acetaminophen consumption on ratings of perceived exertion and estimated time limit responses at the lactate threshold. 98 young regional to national level athletes performed a graded exhausting exercise on an outdoor running track to estimate their maximal aerobic velocity and the velocity associated with their lactate concentration threshold. Urine (30 mL) was collected during this test and analysed for numerous substances. During urinary screening for doping substances, 9 acetaminophen consumers (9.2%) among the 98 included athletes were detected. These

acetaminophen consumers have significantly lower perceived exertion at velocity corresponding to the lactate concentration threshold than nonconsumers (11.9 +/- 2.1 vs 13.6 +/- 2.1, respectively) although they were at the same relative exercise intensity. This result shows that acetaminophen consumption may have mediated the perceived exertion response at the lactate concentration threshold. This may then suggest that the pain induced by training load could be a factor in use of self-prescribed pain relievers. Such consumption must be taken into account by medical staff, trainers, or educators who have to give information on the use and adverse effects of this substance and to propose palliative methods to their athletes.

The purpose of this investigation was to estimate the physiologic strain on players during various soccer training activities. Ten soccer players from the first division soccer league of Turkey were used as subjects. The heart rate responses were measured during 4 types of soccer training. First, the heart rates that corresponded to a blood lactate concentration of both 2 and 4 mM were measured, and then, during the 4 types of training, they were correlated with the proportion of time that the heart rate was below the 2-mM lactate line, between the 2- and 4-mM

lactate lines, and above the 4-mM lactate line. Mean heart rates during friendly match, modified game, tactical training, and technical training activities were 157 +/- 19, 135 +/- 28, 126 +/- 21, and 118 +/- 21 b.min(-1), respectively. The differences between all of these soccer training activities were statistically significant (p < or = 0.01). The results demonstrate that (a) technical and tactical training consisted of very low exercise intensities (most of the heart rates were below the 4-mM lactate level) and (b) the percentages of time that the heart rate correlated to a point above the 4-mM lactate reference level during the friendly match and modified game were 49.6 +/- 27.1% and 23.9 +/- 24.5%, respectively. The practical implications of these findings are that, by using 2- to 4-mM reference lines, coaches can structure heart rate zones that can help determine the individualized exercise intensity for their players as well as estimate overall exercise intensity during soccer training.

Optimal lactate removal was reported to occur at work-rate between 30% and 70% VO2max. However, it has been recently recommended to quantify exercise intensity not in percentage of VO2max but in relation to validated metabolic reference points such as the individual anaerobic threshold (IAT) and the individual ventilatory

threshold (IVT). The purpose of this study was to examine the effect on lactate removal of different recovery work-rates below the IAT defined calculating the difference (DT) between IAT and IVT, then choosing the IVT+50%DT, the IVT and the IVT-50%DT work-rates. METHODS: Eight male triathletes (VO2max 69.7+/−4.7, VO2IAT 52.9+/−4, VO2IVT 41.1+/−4.7 mL x kg(-1) x min(-1)), after a 6-min treadmill run at 75% of difference between IAT and VO2max, performed in a random order the following 30-min recovery treatments: 1) run at IVT(plus;50%DT), 2) at IVT, 3) at IVT(-50%DT), 4) passive. Blood lactate was measured at 1, 3, 6, 9, 12, 15, 20, 25, 30 minutes of recovery. RESULTS: All active recovery work-rates (from 50+/−5% to 67+/−4% VO2max) were within the range previously reported for optimal lactate removal, and significantly more efficient than passive recovery on lactate removal curve (% of accumulated lactate above rest value). However, significant differences (P<0.01) were found among active recovery intensities: the IVT(-50%DT) was the most efficient work-rate from the 9th minute to 30th minute. CONCLUSIONS: In triathletes, the IVT(-50%DT) was the optimal work-rate for lactate removal; moreover none of the studied active work-rate showed further lactate decrease after the 20th minute of recovery.
The maximum lactate steady state (MLSS) represents the highest intensity of exercise at which a balance exists between the rate of lactate production and the rate of lactate clearance. The MLSS is an important determinant of endurance exercise performance but its determination, which involves 4-5 laboratory visits, is labor-intensive and time consuming. PURPOSE: To compare the MLSS estimated from a single-visit protocol (MLSSsingle) with the traditional, directly measured MLSS (MLSStrad). METHODS: Following an incremental treadmill test for the determination of VO2peak, eight endurance-trained runners completed: 1) a series of 4-5 constant-speed treadmill runs of up to 30-min duration, on separate days, for determination of the MLSStrad; and 2) a single-visit protocol consisting of two constant-speed treadmill runs of 20-min duration at approximately 65 and 90% VO2peak separated by 40 min of rest, for determination of MLSSsingle. Blood lactate concentration ([La]), oxygen uptake (VO2), and heart rate (HR) were measured every 5 min in all treadmill runs. Comparisons between values were made using paired t-tests. RESULTS: The MLSSsingle significantly underestimated the MLSStrad with respect to speed (13.4 +/- 1.2 vs 16.4 +/- 1.6 km x h(-1), P = 0.002), HR (148 +/- 8 vs 170 +/- 10 b x min(-1), P < 0.001), blood [La] (2.3 +/- 1.5 vs 3.9 +/- 1.0 mmol x L(-1); P = 0.01), and % VO2peak

utilized (75 +/- 8 vs 90 +/- 2%, P = 0.002). The MLSSStrad speed and MLSSsingle speed were poorly correlated (r = 0.29, P = 0.49).

CONCLUSION: The single-visit method of determining the MLSS substantially underestimates the actual MLSS.

19This study validated the laboratory testing used to monitor on water training. The purpose was to test that reference heart rates (HR) determined during an incremental test elicit comparable blood lactate levels ([La]b) during a 30 min on water rowing. METHODS: Blood lactate profile were determined during incremental graded exercise in 14 national and international level oarsmen. The HR corresponding to [La]b of 2 and 3 mmol x l(-1) were determined (HRLa2 and HRLa3 respectively). The rowers then performed a 30 min training session in a boat. Training intensity, as assessed by HR monitors, had to range between HRLa2 and HRLa3. Field [La]b (Laf) and HR (HRf) were measured at the end of the training session. RESULTS: Laf was 2.13 +/- 0.49 mmol x l(-1) (range: 1.43-3.07) and did not differ significantly from 2 mmol x l(-1). HRf (162 +/- 7.4 beats x min(-1)) ranged from HRLa2 (159 +/- 9.5 beats x min(-1)) to HRLa3 (171 +/- 9 beats x min(-1)). HRf was not significantly different from HRLa2. CONCLUSIONS: It was

concluded that the HR determined during the laboratory testing are valid for monitoring on water training in highly trained rowers.

The classical maximal lactate steady state (MLSS) assessment protocol takes multiple days to measure thus necessitates athletes to return to a laboratory for several visits. The purpose of this study was to assess the validity and reliability of a new protocol (Palmer protocol), which proposes to measure MLSS in a single-day. METHODS: Nine endurance-trained males (age 21.1 +/- 1.6 years, VO2max of 63.2 +/- 3.2 ml x kg(-1) x min(-1)) performed the Palmer protocol and the classical MLSS assessment protocol. The classical MLSS protocol consisted of several constant-velocity runs of increasing intensity. The MLSS was defined as the highest velocity associated with an increase in blood lactate concentration ([La-]) = or < 1.0 mmol x L (-1) during the final 20 min of a 30 min run. Concurrent validity was assessed by calculating a Pearson product correlation coefficient between the running velocity at MLSS from the classical protocol and from the single-day Palmer protocol. Test-retest reliability was assessed by calculating a Pearson product correlation coefficient between the running velocities from 2 separate trials of the single-day Palmer protocol. RESULTS: The velocity at MLSS from the single-day Palmer protocol (236.4 +/- 27.8 m x min(-20)

produced a strong correlation of 0.97 (p<0.001) with the velocity at MLSS from the classical protocol (226.3 +/- 22.6 m x min(-1)). An equally strong correlation was calculated from test-retest reliability of the single-day Palmer protocol (r=0.97), (p<0.001). CONCLUSION: These results suggest that the single-day Palmer protocol is valid and reliable in the estimation of MLSS.

The aims of this study were: (1) to identify the exercise intensity that corresponds to the maximal lactate steady state in adolescent endurance-trained runners; (2) to identify any differences between the sexes; and (3) to compare the maximal lactate steady state with commonly cited fixed blood lactate reference parameters. Sixteen boys and nine girls volunteered to participate in the study. They were first tested using a stepwise incremental treadmill protocol to establish the blood lactate profile and peak oxygen uptake (VO2). Running speeds corresponding to fixed whole blood lactate concentrations of 2.0, 2.5 and 4.0 mmol x l(-1) were calculated using linear interpolation. The maximal lactate steady state was determined from four separate 20-min constant-speed treadmill runs. The maximal lactate steady state was defined as the fastest running speed, to the nearest 0.5 km x h(-1), where the change in blood lactate concentration between 10 and 20 min was < 0.5 mmol x l(-1).

1) Although the boys had to run faster than the girls to elicit the maximal lactate steady state (15.7 vs 14.3 km x h(-1), P < 0.01), once the data were expressed relative to percent peak VO2 (85 and 85%, respectively) and percent peak heart rate (92 and 94%, respectively), there were no differences between the sexes (P > 0.05). The running speed and percent peak VO2 at the maximal lactate steady state were not different to those corresponding to the fixed blood lactate concentrations of 2.0 and 2.5 mmol x l(-1) (P > 0.05), but were both lower than those at the 4.0 mmol x l(-1) concentration (P < 0.05). In conclusion, the maximal lactate steady state corresponded to a similar relative exercise intensity as that reported in adult athletes. The running speed, percent peak VO2 and percent peak heart rate at the maximal lactate steady state are approximated by the fixed blood lactate concentration of 2.5 mmol x l(-1) measured during an incremental treadmill test in boys and girls

22We investigated the validity of different lactate and ventilatory threshold methods, to estimate heart rate and power output corresponding with the maximal lactate steady-state (MLSS) in elite cyclists. Elite cyclists (n = 21; 21 +/- 0.4 y; VO2peak, 5.4 +/- 0.2 l x min (-1)) performed either one (n = 10) or two (n = 11) maximal graded exercise
tests, as well as two to three 30-min constant-load tests to determine MLSS, on their personal race bicycle which was mounted on an ergometer. Initial workload for the graded tests was 100 Watt and was increased by either 5% of body mass (in Watt) with every 30 s (T30 s), or 60% of body mass (in Watt) with every 6 min (T6 min). MLSS was defined as the highest constant workload during which lactate increased no more than 1 mmol x l (-1) from min 10 to 30. In T30 s and T6 min the 4 mmol (TH-La4), the Conconi (TH-Con) and dmax (TH-Dm) lactate threshold were determined. The dmax lactate threshold was defined as the point that yields the maximal distance from the lactate curve to the line formed by the lowest and highest lactate values of the curve. In T30 s also ventilatory (TH-Ve) and Vslope (TH-Vs) thresholds were calculated. Time to exhaustion was 36 +/- 1 min for T30 s versus 39 +/- 1 min for T6 min. None of the threshold measures in T30 s, except TH-Vs (r2 = 0.77 for heart rate) correlated with either MLSS heart rate or power output. During T6 min, power output at TH-Dm was closely correlated with MLSS power (r2=0.72). Low correlations were found between MLSS heart rate and heart rate measured at TH-Dm (r2=0.46) and TH-La4 (r2=0.25), respectively, during T6 min. It is concluded that it is not possible to precisely predict heart rate or power output corresponding with MLSS in elite cyclists, from a single graded exercise test causing
exhaustion within 35-40 min. The validity of MLSS predicted from an incremental test must be verified by a 30-min constant-load test.

The aim of this study was to investigate whether a single soccer specific fitness test (SSFT) could differentiate between highly trained and recreationally active soccer players in selected test performance indicators. METHODS: Subjects: 13 Academy Scholars (AS) from a professional soccer club and 10 Recreational Players (RP) agreed to participate in this study. Test 1--VO(2) max was estimated from a progressive shuttle run test to exhaustion. Test 2--The SSFT was controlled by an automated procedure and alternated between walking, sprinting, jogging and cruise running speeds. Three activity blocks (1A, 2A and 3A) were separated by 3 min rest periods in which blood lactate samples were drawn. The 3 blocks of activity (Part A) were followed by 10 min of exercise at speeds alternating between jogging and cruise running (Part B). RESULTS: Estimated VO(2) max did not significantly differ between groups, although a trend for a higher aerobic capacity was evident in AS (p<0.09). Exercising heart rates did not differ between AS and RP, however, recovery heart rates taken from the 3 min rest periods were significantly lower in AS compared with RP following blocks 1A

(124.65 b x min(-1) +/- 7.73 and 133.98 b x min(-1) +/- 6.63), (p<0.05) and 3A (129.91 b x min(-1) +/- 10.21 and 138.85 b x min(-1) +/- 8.70), (p<0.01). Blood lactate concentrations were significantly elevated in AS in comparison to RP following blocks 2A (6.91 mmol x l(-1) +/- 2.67 and 4.74 mmol x l(-1) +/- 1.28) and 3A (7.18 mmol x l(-1) +/- 2.97 and 4.88 mmol x l(-1) +/- 1.50), (p<0.05). AS sustained significantly faster average sprint times in block 3A compared with RP (3.18 sec +/- 0.12 and 3.31 sec +/- 0.12), (p<0.05). CONCLUSION: The results of this study show that highly trained soccer players are able to sustain, and more quickly recover from, high intensity intermittent exercise.

The aim of this study was to assess physical fitness, match performance and development of fatigue during competitive matches at two high standards of professional soccer. Computerized time-motion analyses were performed 2-7 times during the competitive season on 18 top-class and 24 moderate professional soccer players. In addition, the players performed the Yo-Yo intermittent recovery test. The top-class players performed 28 and 58% more (P < 0.05) high-intensity running and sprinting, respectively, than the moderate players (2.43 +/- 0.14 vs 1.90 +/- 0.12 km and 0.65 +/- 0.06 vs 0.41 +/- 0.03 km, respectively). The top-class players were better (11%; P < 0.05) on the Yo-Yo intermittent

recovery test than the moderate players (2.26 +/- 0.08 vs 2.04 +/- 0.06 km, respectively). The amount of high-intensity running, independent of competitive standard and playing position, was lower (35-45%; P < 0.05) in the last than in the first 15 min of the game. After the 5-min period during which the amount of high-intensity running peaked, performance was reduced (P < 0.05) by 12% in the following 5 min compared with the game average. Substitute players (n = 13) covered 25% more (P < 0.05) ground during the final 15 min of high-intensity running than the other players. The coefficient of variation in high-intensity running was 9.2% between successive matches, whereas it was 24.8% between different stages of the season. Total distance covered and the distance covered in high-intensity running were higher (P < 0.05) for midfield players, full-backs and attackers than for defenders. Attackers and full-backs covered a greater (P < 0.05) distance in sprinting than midfield players and defenders. The midfield players and full-backs covered a greater (P < 0.05) distance than attackers and defenders in the Yo-Yo intermittent recovery test (2.23 +/- 0.10 and 2.21 +/- 0.04 vs 1.99 +/- 0.11 and 1.91 +/- 0.12 km, respectively). The results show that: (1) top-class soccer players performed more high-intensity running during a game and were better at the Yo-Yo test than moderate professional players; (2) fatigue occurred towards the end of matches as well as temporarily during the game, independently of competitive standard and of team position; (3)
defenders covered a shorter distance in high-intensity running than players in other playing positions; (4) defenders and attackers had a poorer Yo-Yo intermittent recovery test performance than midfielders and full-backs; and (5) large seasonal changes were observed in physical performance during matches.

Increased participation of aged individuals in athletics warrants basic research focused on delineating age-related changes in performance variables. On the basis of potential age-related declines in aerobic enzyme activities and a shift in the expression of myosin heavy chain (MHC) isoforms, we hypothesized that maximal lactate steady-state (MLSS) exercise intensity would be altered as a function of age. Three age groups [young athletes (YA), 25.9 +/- 1.0 yr, middle-age athletes (MA), 43.2 +/- 1.0 yr, and older athletes (OA), 64.6 +/- 2.7 yr] of male, competitive cyclists and triathletes matched for training intensity and duration were studied. Subjects performed a maximal O2 consumption (V(o2 max)) test followed by a series of 30-min exercise trials to determine MLSS. A muscle biopsy of the vastus lateralis was procured on a separate visit. There were differences (P < 0.05) in V(o2 max) among all age groups (YA = 67.7 +/- 1.2 ml x kg-1 x min-1, MA = 56.0 +/- 2.6 ml x kg-1 x min-1, OA = 47.0 +/- 2.6 ml x kg-1 x min-1). When expressed

as a percentage of V(o2 max), there was also an age-related decrease (P < 0.05) in the relative MLSS exercise intensity (YA = 80.8 +/- 0.9%, MA = 76.1 +/- 1.4%, OA = 69.9 +/- 1.5%). There were no significant age-related changes in citrate synthase activity or MHC isoform profile. The hypothesis is supported as there is an age-related decline in MLSS exercise intensity in athletes matched for training intensity and duration. Although type I MHC isoform, combined with age, is helpful in predicting (r = 0.76, P < 0.05) relative MLSS intensity, it does not explain the age-related decline in MLSS.

The maximal lactate steady state (MLSS) is the highest blood lactate concentration (BLC) that can be identified as maintaining a steady-state during a prolonged submaximal constant workload. Comparative interpretation of published data about MLSS is complicated by the fact that different methods of testing have been utilized. Thus, three methods, corresponding to the time course of changes in BLC incurred during either 30 min (MLSS I) or 20 min (MLSS II and III) of constant submaximal workload exercise, were compared in 26 male subjects [mean (SD) age 24.6 (5.6) years, height 181.6 (4.9) cm, body mass 74.4 (5.2) kg]. MLSS I [5.1 (1.3) mmol x l(-1)], II [4.9 (1.3) mmol x l(-1)], and III [4.3 (1.3) mmol x l(-1)] were different (P<0.01). The

workload corresponding to MLSS III [244.8 (44.0) W] was lower (P<0.01) than that at MLSS I [254.0 (40.8) W] and II [251.9 (40.4) W]. No difference could be confirmed between the workloads established for MLSS I and MLSS II. The differences between MLSS I, MLSS II, and MLSS III and corresponding workloads reflect insufficient contribution to lactate kinetics by testing procedures that depend strongly upon the time course of changes in BLC during the initial 20-25 min of constant-workload exercise. Based on the present findings, constant-load tests lasting at least 30 min and a BLC increase of no more than 1.0 mmol x l(-1) after the 10th testing minute appear to be the most reasonable with respect to valid testing results.

The maximal lactate steady state (MLSS) is defined as the highest blood lactate concentration (MLSSc) and work load (MLSSw) that can be maintained over time without a continual blood lactate accumulation. A close relationship between endurance sport performance and MLSSw has been reported and the average velocity over a marathon is just below MLSSw. This work rate delineates the low- to high-intensity exercises at which carbohydrates contribute more than 50% of the total energy need and at which the fuel mix switches (crosses over) from predominantly fat

to predominantly carbohydrate. The rate of metabolic adenosine triphosphate (ATP) turnover increases as a direct function of metabolic power output and the blood lactate at MLSS represents the highest point in the equilibrium between lactate appearance and disappearance both being equal to the lactate turnover. However, MLSSc has been reported to demonstrate a great variability between individuals (from 2-8 mmol/L) in capillary blood and not to be related to MLSSw. The fate of enhanced lactate clearance in trained individuals has been attributed primarily to oxidation in active muscle and gluconeogenesis in liver. The transport of lactate into and out of the cells is facilitated by monocarboxylate transporters (MCTs) which are transmembrane proteins and which are significantly improved by training. Endurance training increases the expression of MCT1 with intervariable effects on MCT4. The relationship between the concentration of the two MCTs and the performance parameters (i.e. the maximal distance run in 20 minutes) in elite athletes has not yet been reported. However, lactate exchange and removal indirectly estimated with velocity constants of the individual blood lactate recovery has been reported to be related to time to exhaustion at maximal oxygen uptake.
To determine whether repetitive test interruptions (TI) during constant load testing influence blood lactate concentration (BLC), maximal lactate steady state (MLSS), MLSS workload (P-MLSS), and relative MLSS intensity (Int-MLSS). METHODS: Nineteen males participated in this study. In experiment A, 10 subjects (27.5 +/- 2.9 yr; 183.7 +/- 5.2 cm; 77.4 +/- 3.7 kg) performed 30-min constant load tests: one without TI, one with TI of 30 s, and one with TI of 90 s after every 5 min of cycling at a given workload. In experiment B, nine subjects (28.0 +/- 2.7 yr; 182.9 +/- 6.8 cm; 76.2 +/- 4.5 kg) performed 30-min constant load tests at different workloads until MLSS had been determined for all three TI protocols. RESULTS: In experiment A, the BLC after 30 min net working time (BLC30) was higher (P < 0.001) without TI (6.0 +/- 1.3 mmol.l(-1)) than with TI of 30 s (4.9 +/- 1.4 mmol.l(-1)) or 90 s (4.5 +/- 1.1 mmol.l(-1)). The change in BLC during the final 20 min (DeltaBLC10-30) was greater (P < 0.01) without TI (1.2 +/- 1.0 mmol.l(-1)) than with TI of 30 s (0.2 +/- 0.7 mmol.l(-1)) or 90 s (-0.3 +/- 0.7 mmol.l(-1)). In experiment B, the MLSS was not affected, but P-MLSS and Int-MLSS were lower (P < 0.01) without TI (277.8 +/- 24.4W and 73.7 +/- 7.6%) than with TI of 30 s (300.4 +/- 30.4W and 79.2 +/- 8.0%) or 90 s (310.0 +/- 31.2W and 81.5 +/- 7.1%). Approximately 35% of the

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variance of BLC30 and DeltaBLC10-30, and 70% of the variance of P-MLSS and Int-MLSS were explained by TI duration (P < 0.001).

CONCLUSIONS: TI decreased BLC30 and DeltaBLC10-30 but has no effect on MLSS. Consequently, with TI, the MLSS is achieved at higher P-MLSS and Int-MLSS.

The aim of this study was to investigate the reproducibility of blood lactate measurements, heart rate (HR) and ratings of perceived exertion (RPE) during treadmill exercise at speeds corresponding to the lactate threshold (v(Th,la)) and a fixed blood lactate concentration of 4 mmol.L(-1)(v(la),(4)). Possible differences in reproducibility related to fitness levels were also investigated. A group of 20 men [mean (SD)] [age 20.5 (1.4) years] and 16 women [age 21.2 (0.9) years] took part in the study. The subjects performed two identical incremental exercise tests consisting of at least six 4 min stages. Blood lactate concentrations, HR and RPE were recorded at the end of each stage. Limits of agreement (LoA), correlation coefficients and 95% confidence intervals for the mean difference between tests were employed to investigate the level of agreement and reproducibility of blood lactate concentration, HR and RPE. For the group as a whole, the sample correlation coefficient for

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speed at v(Th,la) was r=0.88, and was r=0.92 for the speed at v(la)-(4). At v(Th,la) -, the correlation coefficients for the moderately fit and unfit were r=0.94 and r=0.36, respectively, and at v(la)-(4) r=0.93 and r=0.68, respectively. The LoA for the moderately fit group indicated that a change of 1.62 km.h(-1) in v(Th,la) would be necessary to be considered a change in training status. For HR and RPE, relationships between the tests were generally poor. The LoA suggested that changes in scores must be unacceptably large. These findings cast doubt on the sensitivity of testing for change of blood lactate concentration, HR and RPE in this population.

30 The effects of 4 weeks of endurance training in conditions of normoxia or hypoxia on muscle characteristics and blood lactate responses after a 5-min constant-load exercise (CLE) at 90% of the power corresponding to the maximal oxygen uptake were examined at sea-level in 13 sedentary subjects. Five subjects trained in normobaric hypoxia (HT group, fraction of oxygen in inspired gas = 13.2%), and eight subjects trained in normoxia at the same relative work rates (NT group). The blood lactate recovery curves from the CLE were fitted to a biexponential time function: La(t) = La(0) + A1(1 - e- gamma 1.t) + A2(1 - e- gamma

2.t), where the velocity constants gamma 1 and gamma 2 denote the lactate exchange and removal abilities, respectively, A1 and A2 are concentration parameters that describe the amplitudes of concentration variations in the space represented by the arterial blood, La(t) is the lactate concentration at time t, and La(0) is the lactate concentration at the beginning of recovery from CLE. Before training, the two groups displayed the same muscle characteristics, blood lactate kinetics after CLE, and gamma 1 and gamma 2 values. Training modified their muscle characteristics, blood lactate kinetics and the parameters of the fits in the same direction, and proportions among the HT and the NT subjects. Endurance training increased significantly the capillary density (by 31%), citrate synthase activity (by 48%) and H isozyme proportion of lactate dehydrogenase (by 24%), and gamma 1 (by 68%) and gamma 2 (by 47%) values. It was concluded that (1) endurance training improves the lactate exchange and removal abilities estimated during recovery from exercises performed at the same relative work rate, and (2) training in normobaric hypoxia results in similar effects on lactate exchange and removal abilities to training in normoxia performed at the same relative work rates. These results, which were obtained non-invasively in vivo in humans during recovery from CLE, are comparable to those obtained in vitro or by invasive methods during exercise and subsequent recovery.
We determined the plasma lactate concentrations for 11 well-trained endurance cyclists or triathletes during a laboratory trial to measure maximal distance cycled in 1 h. METHODS: Subjects performed three distance trials, cycling as far as possible in 1 h. Blood samples were taken from a forearm vein every 10 min during the third trial (T). Samples were analyzed by spectrophotometer for plasma lactate concentrations ([La]). RESULTS: During T, subjects cycled 40.8+/−2.2 km at an average of 83+/−4% of their predicted maximum heart rate (HRmax). Minimum and maximum [La] for each subject was noted for minutes 10, 20, 30, 40, and 50. Minimum [La] ranged between 2.8 and 10.3 mmol x L(-1), and maximum [La] ranged between 5.8 and 13.6 mmol x L(-1). The average [La] from minute 10 to 50 was calculated for each subject and ranged from 5.0 to 12.3 mmol x L(-1). This did not correlate with performance (distance covered in 1 h). Therefore, there was a wide range of individual plasma lactate responses to the same laboratory test that simulated an actual race. The overall average [La] for all subjects was 7.6+/−2.1 mmol x L(-1). CONCLUSIONS: These data indicate first that the value of 4 mmol x L(-1), commonly referred to as OBLA, may often underestimate the upper limit of tolerance to lactate.

during a maximal endurance performance test lasting approximately 1 h. Second, during this type of work, intersubject differences in average plasma lactate concentration do not correlate with performance.

\[ ^{32} \text{Blood lactate concentration (BLC) can be used to monitor relative exercise intensity. The highest BLC representing an equilibrium between lactate production and elimination is termed maximal lactate steady state (MLSS). MLSS is used to discriminate qualitatively between continuous exercise, which is limited by stored energy, from other types of exercise terminated because of disturbance of cellular homoeostasis.} \]

AIM: To investigate the hypothesis that MLSS intraindividually depends on the mode of exercise. METHODS: Six junior male rowers (16.5 (1.4) years, 181.7 (3.1) cm, 69.8 (3.3) kg) performed incremental and constant load tests on rowing and cycle ergometers. Measurements included BLC, sampled from the hyperaemic ear flap, heart rate, and oxygen uptake. MLSS was defined as the highest BLC that increased by no more than 1.0 mmol/l during the final 20 minutes of constant workload. RESULTS: In all subjects, MLSS was lower (p < or = 0.05) during rowing (2.7 (0.6) mmol/l) than during cycling (4.5 (1.0) mmol/l). No differences between rowing and cycling were found with respect to MLSS heart rate (169.2 (9.3) v 172.3 (6.7) beats/min), MLSS workload (178.7 (29.8) v 205.0

MLSS intensity expressed as a percentage (63.3 (6.6)% v 68.6 (3.8)%) of peak workload (280.8 (15.9) v 299.2 (28.4) W) or percentage (76.4 (3.4)% v 75.1 (3.0)%2) of peak oxygen uptake (60.4 (3.4) v 57.2 (8.6) ml/kg/min). CONCLUSIONS: In rowing and cycling, the MLSS but not MLSS workload and MLSS intensity intraindividually depends on the motor pattern of exercise. MLSS seems to decrease with increasing mass of the primarily engaged muscle. This indicates that task specific levels of MLSS occur at distinct levels of power output per unit of primarily engaged muscle mass.

Changes in physiological variables during a 60-min continuous test at maximal lactate steady state (MLSS) were studied using highly conditioned cyclists (1 female and 9 males, aged 28.3 +/- 8.1 years). To determine power at MLSS, we tested at 8-min increments and interpolated the power corresponding to a blood lactate value of 4 mmol/L. During the subsequent 60-min exercise at MLSS, we observed a sequential increase of physiological parameters, in contrast to stable blood lactate. Heart rate drifted upward from beginning to end of exercise. This became statistically significant after 30 min. From 10-60 min of exercise, a change of +12.6 +/- 3.2 bpm was noted. Significant drift was seen after 30 min for the respiratory exchange ratio, after 40 min

for the rate of perceived exertion using the Borg scale, and after 50 min for % VO(2)max/kg and minute ventilation. This slow component of VO(2)max may be the result of higher recruitment of type II fibers.

The maximal lactate steady state (MLSS) corresponds to the highest workload that can be maintained over time without a continual blood lactate accumulation. MLSS and MLSS intensity have been speculated to depend on performance. Experimental proof of this hypothesis is missing. METHODS: 33 male subjects (age: 23.7 +/- 5.5 yr, height: 181.2 +/- 5.3 cm, body mass: 73.4 +/- 6.4 kg) performed an exhausting incremental load test to measure peak workload and three to six 30-min constant load tests on a cycle ergometer to determine MLSS. RESULTS: MLSS (4.9 +/- 1.4 mmol x L(-1)) was independent of MLSS workload (3.4 +/- 0.6 W x kg(-1)) and peak workload (4.8 +/- 0.6 W x kg(-1)). MLSS intensity (71.1 +/- 6.7%) did not correlate with peak workload or MLSS (P > 0.05). A positive correlation was found between peak workload and MLSS workload (r = 0.82, P < 0.001).

CONCLUSIONS: MLSS and MLSS intensity are independent of performance but subjects with higher maximum performance have higher MLSS workloads. The combination of various fitness related effects on both, the production and the disappearance of lactate during exercise,

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may explain that different MLSS workloads coincide with similar levels of MLSS and MLSS intensity.

The individual anaerobic threshold (IAT) is defined (18) as the highest metabolic rate where blood lactate (La) concentrations are maintained at a steady-state during prolonged exercise. Stegmann et al.'s (18) method to detect IAT, using La-performance relationship during incremental graded exercise, is based on the assumption that La is in relatively steady state by the end of each 3-min stage of work rate. However, at the end of a 3-min stage, an La steady state (Lass) is not reached (13). PURPOSE: The present study was designed to investigate whether the IAT should be determined by attributing La value to the antecedent stage (IATa) or to the same stage of its measurement (IATm), then to verify whether this IAT would be a valid indicator of the max Lass during prolonged exercise. METHODS: Forty-one athletes (21 male and 20 female), regularly involved in different physical training, performed three exercise tests on treadmill. The first one was a 3-min stage incremental test to detect the IATa and IATm. The other two tests were 30-min prolonged tests at the IATa and IATm workload. Lass were present in IATa intensity (about 4.0 mmol x L(-1)) both in male and female athletes, whereas at IATm intensity a Lass was not present and a

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premature break-off occurred in some cases. DISCUSSION: This protocol can be useful for practical use because: 1) the method of choosing the anaerobic threshold is easy to apply; 2) it does not require to reach the maximal effort; and 3) although in some cases the IATa could probably underestimate the workload of max Lass, the IATa can be regarded as guideline to define the intensity of endurance training.

Capillary blood lactate assessment is increasingly used by well-trained runners to monitor the intensity of endurance exercise. In order to examine the known association of exercise intensity with blood lactate accumulation also in less trained subjects, we analysed data from a standardized incremental maximal test on the treadmill of 319 men (age 22.9 +/- 5.5 years, [means +/- S.D.]) and 145 women (22.7 +/- 4.5 years) characterized by a wide variation in endurance capacity. Results showed that the running velocity eliciting a blood lactate concentration of 4 mmol/l did not correspond to the same exercise intensity in well endurance-trained vs poorly endurance-trained subjects. At 4 mmol/l blood lactate, the slowest decile of men (i.e. 32 out of 319) ran at 71 +/- 4.7% (corresponding to 2.9 +/- 0.3 m/s) of their maximal treadmill velocity attained during the test (4.1 +/- 0.4 m/s), indicating a rating of perceived exertion (RPE) of 12.3 +/- 1.8 points (Borg scale, range 6-20

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points), while the fastest decile of men (n = 32) ran at 91 +/- 3.1% (corresponding to 5.4 +/- 0.2 m/s) of their maximal treadmill speed (5.9 +/- 0.2 m/s), indicating a RPE of 16.6 +/- 1.1 points. Very similar results were observed in women. There was a highly significant, positive correlation between running speed eliciting a blood lactate concentration of 4 mmol/l and RPE when running at this speed, with $r = 0.64$ in men and $r = 0.55$ in women. At the same proportional level of maximal running velocity, poorly endurance-trained athletes showed a 2-3 mmol/l higher capillary lactate concentration than well endurance-trained athletes, with both groups indicating the same RPE. These results suggest that fixed blood lactate concentrations not at all mean the same exercise intensity for well vs poorly endurance-trained subjects; this systemic trend should be considered when using blood lactate assessment for individual exercise counselling.

Identification of the maximal lactate steady state (MLSS) involves multiple days of testing. Heart rate (HR), rating of perceived exertion (RPE), breathing frequency (bf), and race pace may be useful in estimating the MLSS, thus allowing for testing to occur in a single day. The purpose of this investigation was to design a single-session protocol for determining MLSS using HR, RPE, bf, and race pace as predictors.

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METHODS: Twelve endurance athletes (mean +/- SD, VO2max 64.6 +/- 7.8 mL x kg(-1) x min(-1)) performed the MLSS protocol run and two 27-min validation runs on a treadmill. Running velocity at 87% HRmax RPE of 12, bf of 32 breaths x min(-1), and race pace were used as a starting point for testing. Blood was collected every 3 min of each 9-min stage of the protocol run and analyzed for lactate (La) concentration. The velocity associated with the MLSS was determined as the average of the stage of La steady state and the stage of La accumulation. Validation runs were performed at a velocity 7.5 m x min(-1) below and 7.5 m x min(-1) above the protocol-determined MLSS. If the slower run exhibited a La steady state and the faster run an accumulation of La, then the protocol-determined MLSS value was considered valid. RESULTS: The protocol run was successful in predicting the MLSS in 9 out of 12 subjects (P < or = 0.05). CONCLUSIONS: The proposed protocol employing HR, RPE, bf, and race pace as a starting point for testing can be used to identify the MLSS in one testing session.

Maximum lactate steady state (MLSS) is defined as the highest steady state exercise level one can maintain while also maintaining an equilibrium between the elimination of blood lactate and the diffusion of lactate into the blood. MLSS is an excellent tool for assessing fitness

level, predicting endurance performance, and designing training programs. METHODS: This investigation assesses the validity of the Lactate Minimum Test (LMT), which consists of inducing lactic acidosis through a VO2peak test, followed by an eight-minute walking recovery and an incremental exercise test, to determine if the running velocity associated with the minimum lactate value predicts the MLSS velocity. Following this LMT, two constant velocity 28-minute runs were performed, one at the predicted MLSS velocity (trial 1) and the other 0.13 m sec-1 (4-8%) above the predicted MLSS velocity (trial 2). Ten active female subjects participated (32 +/- 7 yrs (mean +/- SD); 65.7 +/- 16.4 kg; VO2peak 40.0 +/- 7.5 ml.kg-1.min-1). RESULTS: During trial 1, there was a -0.6 +/- 0.3 mmol l-1 (mean +/- SE) change in lactate. Based on a definition of lactate steady state (LSS) as less than a 0.5 mmol.l-1 increase, this value signified LSS. A similar comparison during trial 2 revealed a 1.8 +/- 0.3 mmol.l-1 increase in lactate, signifying a workload above LSS and therefore confirming trial 1 as the maximum LSS (MLSS). CONCLUSIONS: These results suggest that the test protocol accurately predicted the MLSS velocity.

39 The purposes of this study were to estimate noninvasively the maximal lactate steady state (MLSS) in trained cyclists on a windload

simulator with a velocity based technique and to determine whether the HR at MLSS (HR(MLSS)) elicited a similar blood lactate concentration (BLC) during field testing. METHODS: To determine and verify MLSS, 10 male cyclists performed five to seven laboratory trials on separate days, including a VO2max test; a 5-km time trial (TT); and two or more 30-min trials at specific percentages of each subject's average 5-km TT speed (AVS5km). Mean +/- SD for the following variables were obtained at MLSS: velocity was 90.3 +/- 2.7% of the AVS5km, BLC was 5.4 +/- 1.6 mM, RPE was 15 +/- 2.1, VO2 was 80 +/- 6.3% of VO2max, and HR was 167 +/- 9.5 beats x min(-1), which was 88 +/- 3.8% of the mean maximum HR. Field tests included three laps of an 8-km road circuit at HR(MLSS) +/- 3 beats x min(-1) and one lap at maximum sustainable velocity (a road TT). RESULTS: There were no significant differences in BLC, HR, and RPE between the three steady-state road laps and the lab MLSS trial. There was also good agreement between the road and lab MLSS velocity/TT velocity ratios. Conclusions: Our data suggest that 5-km TT cycling velocity, as measured on a windload simulator, may be used to estimate MLSS and the HR at MLSS for training purposes.
Capillary blood lactate assessment is increasingly used by well-trained runners to monitor the intensity of endurance exercise. In order to examine the known association of exercise intensity with blood lactate accumulation also in less trained subjects, we analysed data from a standardized incremental maximal test on the treadmill of 319 men (age 22.9 +/- 5.5 years, [means +/- S.D.]) and 145 women (22.7 +/- 4.5 years) characterized by a wide variation in endurance capacity. Results showed that the running velocity eliciting a blood lactate concentration of 4 mmol/l did not correspond to the same exercise intensity in well endurance-trained vs poorly endurance-trained subjects. At 4 mmol/l blood lactate, the slowest decile of men (i.e. 32 out of 319) ran at 71 +/- 4.7% (corresponding to 2.9 +/- 0.3 m/s) of their maximal treadmill velocity attained during the test (4.1 +/- 0.4 m/s), indicating a rating of perceived exertion (RPE) of 12.3 +/- 1.8 points (Borg scale, range 6-20 points), while the fastest decile of men (n = 32) ran at 91 +/- 3.1% (corresponding to 5.4 +/- 0.2 m/s) of their maximal treadmill speed (5.9 +/- 0.2 m/s), indicating a RPE of 16.6 +/- 1.1 points. Very similar results were observed in women. There was a highly significant, positive correlation between running speed eliciting a blood lactate concentration of 4 mmol/l and RPE when running at this speed, with r = 0.64 in men.

and $r = 0.55$ in women. At the same proportional level of maximal running velocity, poorly endurance-trained athletes showed a 2-3 mmol/l higher capillary lactate concentration than well endurance-trained athletes, with both groups indicating the same RPE. These results suggest that fixed blood lactate concentrations not at all mean the same exercise intensity for well vs poorly endurance-trained subjects; this systemic trend should be considered when using blood lactate assessment for individual exercise counselling.

A blood lactate concentration of 4 mmol x l-1 (OBLA) is frequently used as an indicator of the maximal steady state of lactate (MLSS) for workload planning in training programs. The aim of the present investigation was to compare several metabolic parameters determined at OBLA and at a fixed heart rate of 175 beats x min-1 (HR175) in amateur cyclists (AC) and professional cyclists (PC). Sixteen AC and 22 PC performed an exercise test on a cycle ergometer following a ramp protocol (25 W x min-1, 70-80 rpm) to exhaustion. Gaseous exchange was monitored throughout the test. VO2, %VO2 max, and power output (W) corresponding to OBLA and HR175 were determined and mean values compared using a Student's t-test. Findings indicated higher VO2 max and W in general in PC ($p<0.01$), and higher VO2 and

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41 Chicharro JL, Carvajal A, Pardo J, Perez M, Lucia A. Physiological parameters determined at OBLA vs. a fixed heart rate of 175 beats x min-1 in an incremental test performed by amateur and professional cyclists. *Jpn J Physiol.* 1999 Feb;49(1):63-9
W at OBLA and HR175 in PC (p<0.01). No significant difference was found between values determined at OBLA and HR175 in the AC group, while in the PC group, VO2, %VO2 max, and W were higher at OBLA. These observations suggest the possible use of a fixed, reference HR of 175 beats x min⁻¹ to determine the exercise intensity corresponding to OBLA in amateur cyclists. This was not the case for the professional cyclists.

42The purpose of this study was to develop a method to determine the power output at which oxygen uptake (VO2) during an incremental exercise test begins to rise non-linearly. A group of 26 healthy non-smoking men [mean age 22.1 (SD 1.4) years, body mass 73.6 (SD 7.4) kg, height 179.4 (SD 7.5) cm, maximal oxygen uptake (VO2max) 3.726 (SD 0.363) l x min(-1)], experienced in laboratory tests, were the subjects in this study. They performed an incremental exercise test on a cycle ergometer at a pedalling rate of 70 rev x min(-1). The test started at a power output of 30 W, followed by increases amounting to 30 W every 3 min. At 5 min prior to the first exercise intensity, at the end of each stage of exercise protocol, blood samples (1 ml each) were taken from an antecubital vein. The samples were analysed for plasma lactate

concentration [La]pl, partial pressure of O2 and CO2 and hydrogen ion concentration [H+]b. The lactate threshold (LT) in this study was defined as the highest power output above which [La]-pl showed a sustained increase of more than 0.5 mmol x l(-1) x step(-1). The VO2 was measured breath-by-breath. In the analysis of the change point (CP) of VO2 during the incremental exercise test, a two-phase model was assumed for the 3rd-min-data of each step of the test: \( X_i = a(i) + b + \varepsilon(i) \) for \( i = 1, 2, ..., T \), and \( E(X_i) > a(i) + b \) for \( i = T + 1, ..., n \), where \( X_1, ..., X_n \) are independent and \( \varepsilon(i) \) approximately \( N(0, \sigma^2) \). In the first phase, a linear relationship between VO2 and power output was assumed, whereas in the second phase an additional increase in VO2 above the values expected from the linear model was allowed. The power output at which the first phase ended was called the change point in oxygen uptake (CP-VO2). The identification of the model consisted of two steps: testing for the existence of CP and estimating its location. Both procedures were based on suitably normalised recursive residuals. We showed that in 25 out of 26 subjects it was possible to determine the CP-VO2 as described in our model. The power output at CP-VO2 amounted to 136.8 (SD 31.3) W. It was only 11 W -- non significantly -- higher than the power output corresponding to LT. The VO2 at CP-VO2 amounted to 1.828 (SD 0.356) l x min(-1) was [48.9 (SD 7.9)% VO2max]. The [La]-pl at CP-VO2, amounting to 2.57 (SD 0.69) mmol x l(-1) was significantly
elevated (P < 0.01) above the resting level [1.85 (SD 0.46) mmol x l(-1)], however the [H+]b at CP-VO2 amounting to 45.1 (SD 3.0) nmol x l(-1), was not significantly different from the values at rest which amounted to 44.14 (SD 2.79) nmol x l(-1). An increase of power output of 30 W above CP-VO2 was accompanied by a significant increase in [H+]b above the resting level (P = 0.03).

The upper limit of blood lactate resulting in a lactate steady state during prolonged exercise is called the maximal lactate steady state (MLSS). The purpose of this study was to investigate the lactate response to steady-state exercise during a field test in elite endurance athletes. Plasma lactate levels were assessed in 13 elite triathletes and 13 elite cyclists (mean +/- SD; age 23.7 +/- 5.1 yr; HT 180.2 +/- 6.3 cm; WT 70.3 +/- 5.9 kg; VO2 max 68 +/- 3.7 ml/min/kg) during a 40 km-long time trial on a bicycle (4 km course x 10 laps). The steady state was demonstrated by monitoring the heart rate and timing every course run. The lactate levels were expected to correspond to MLSS. The mean level of lactate during the time trial was 7.4 +/- 2.5 mmol/l. Five athletes maintained plasma lactate levels which exceeded 10 mmol/l or more for almost 1 h. The large value of individual variability was conspicuous (range 3.2-12.2 mmol/l). These values exceeded all previous reported levels for MLSS.

from other investigators. Our observations are important in sport medical practice since the different lactate responses to exercise are used as parameters in training management.

44 Considering the protective effect of physical activity against coronary heart disease, the estimation of endurance capacity is not only recommended for sportsmen but is also useful for exercise counselling of unfit persons. Endurance capacity can be estimated with test protocols leading to complete exhaustion, or by submaximal test procedures. Submaximal tests have the advantage of putting less stress on subjects than maximal test protocols; on the other hand, they are less accurate. As a complement to traditional submaximal test protocols based on heart rate analysis, a new submaximal protocol is proposed based on measurements of capillary blood lactate concentration during exercise. Incremental tests of 319 men with wide variation of endurance capacity were used to calculate nomograms of the typical pattern of exercise-induced increase in capillary blood lactate concentration, heart rate, and rating of perceived exertion in relation to endurance capacity. The running velocity eliciting a capillary blood concentration of 4 mmol/l lactate was selected as the parameter for endurance capacity. With the help of these nomograms, the 4 mmol/l-velocity could be estimated with submaximal values of lactate,

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heart rate or rating of perceived exertion. The appropriateness of the
nomograms was checked against the data of 100 independent maximal
treadmill tests. Estimation of 4 mmol/l-velocity with submaximal lactate
values showed good precision (with a small standard deviation of +/-0.17
m/s); in contrast, the estimation of endurance capacity with submaximal
values for heart rate and rating of perceived exertion showed substantially
larger standard deviations (approximately +/-0.56 m/s). We conclude that,
for estimation of endurance capacity from submaximal running values,
the nomogram for blood lactate concentrations can be recommended.

Maximal lactate steady state (MLSS) refers to the upper limit of
blood lactate concentration indicating an equilibrium between lactate
production and lactate elimination during constant workload. The aim of
the present study was to investigate whether different levels of MLSS
may explain different blood lactate concentration (BLC) levels at
submaximal workload in the sports events of rowing, cycling, and speed
skating. Eleven rowers (mean +/- SD, age 20.1 +/- 1.5 yr, height 188.7 +/-
6.2 cm, weight 82.7 +/- 8.0 kg), 16 cyclists and triathletes (age 23.6 +/-
3.0 yr, height 181.4 +/- 5.6 cm, weight 72.5 +/- 6.2 kg), and 6 speed
skaters (age 23.3 +/- 6.6 yr, height 179.5 +/- 7.5 cm, weight 73.2 +/- 5.6

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kg) performed an incremental load test to determine maximal workload and several submaximal 30-min constant workloads for MLSS measurement on a rowing ergometer, a cycle ergometer, and on a speed-skating track. Maximal workload was higher (P < or = 0.05) in rowing (416.8 +/- 46.2 W) than in cling (358.6 +/- 34.4 W) and speed skating (383.5 +/- 40.9 W). The level of MLSS differed (P < or = 0.001) in rowing (3.1 +/- 0.5 mmol.l-1), cycling (5.4 +/- 1.0 mmol.l-1), and in speed skating (6.6 +/- 0.9 mmol.l-1). MLSS workload was higher (P < or = 0.05) in rowing (316.2 +/- 29.9 W) and speed skating (300.5 +/- 43.8 W) than in cycling (257.8 +/- 34.6 W). No differences (P > 0.05) in MLSS workload were found between speed skating and rowing. MLSS workload intensity as related to maximal workload was independent (P > 0.05) of the sports event: 76.2% +/- 5.7% in rowing, 71.8% +/- 4.1% in cycling, and 78.1% +/- 4.4% in speed skating. Changes in MLSS do not respond with MLSS workload, the MLSS workload intensity, or with the metabolic profile of the sports event. The observed differences in MLSS and MLSS workload may correspond to the sport-specific mass of working muscle.

46 Maximal lactate steady state (MLSS) presumably corresponds to the highest constant workload that can be performed by oxidative
metabolism. The anaerobic and, to a minor extent, the oxidative metabolism have been reported to be affected by age. The second decade of life is the key period in the change in energy metabolism between children and adults. The aim of this study was to evaluate the effects of age on MLSS in 34 male subjects (age: 15.4 +/- 2.8 yr, range: 11-20 yr; height: 171.8 +/- 14.9 cm, range: 134-191 cm; body mass: 59.6 +/- 15.5 kg, range: 27-90 kg) performing an incremental load test to determine maximal workload and several constant load tests for MLSS measurement on a cycle ergometer. MLSS (4.2 +/- 0.7 mmol.l-1, range: 2.8 to 5.5 mmol.l-1) and MLSS intensity related to maximal workload (66.5 +/- 7.7%, range: 50-84%) were independent of age. MLSS heart rate (180.1 +/- 10.1 min-1, range: 156-208 min-1) decreased (P < 0.01) with increasing age, whereas absolute (157.2 +/- 54.8 W, range: 65-240 W) and relative MLSS workload (2.6 +/- 0.5 W.kg-1, range: 1.5 to 4.1 W.kg-1) and absolute (236.9 +/- 79.0 W, range: 100-350 W) and relative maximal workload (3.9 +/- 0.6 W.kg-1, range: 2.7 to 5.5 W.kg-1) increased (P < 0.001) with age. The age independence of MLSS supports the theory that neuromuscular factors may contribute to the frequently observed changes in response to given exercise with physical maturity more than changes in oxidative metabolism and/or glycolysis.

Anaerobic threshold, also termed 4.0 mmol.l⁻¹ threshold (AT4), and individual anaerobic threshold (IAT), presumably indicate the workload corresponding to maximal lactate steady state (MLSS) during an incremental workload test. MLSS is the highest blood lactate concentration (BLC) resulting in a steady state during constant workload. The purpose of the present investigation was to ascertain the validity of AT4 and IAT as related to MLSS during rowing ergometry. Nine rowers (mean ± SD age 20.2 ± 1.6 yr; HT 187.2 ± 4.9 cm; WT 81.1 ± 6.3 kg) performed an incremental load test to determine AT4, IAT and maximal workload and several 30 min constant workloads for MLSS measurement on a mechanical rowing ergometer. The incremental load test was conducted at 215 W and increased by 35 W every 3.0 min. The first 30 min constant workload was conducted at 60% of maximal workload (363.3 ± 45.1 W). If a constant load test resulted in a steady state of BLC subsequent constant load tests were performed and workload increased by 3% to 10% after each constant load test until no steady state of BLC could be observed. AT4 (287.0 ± 20.5 W), IAT (287.1 ± 25.1 W), and BLC at IAT (4.2 ± 0.8 mmol.l⁻¹) were higher (P < 0.001) compared to MLSS workload (255.1 ± 17.5 W) and MLSS (3.0 ± 0.6 mmol.l⁻¹), respectively. Independent of the practical

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application of AT4 and IAT, in rowing AT4 and IAT do not represent MLSS workload.

The subject group comprised 35 endurance-trained males: 11 young adults, 11 seniors and a control group of 13 young adults. A graded submaximal exercise test on a treadmill was performed by 22 of the subjects. The exponential function \[ [\text{La}^{-}] = a \cdot e^{bx} + c \] (where \( x = \) running velocity) showed a high degree of correlation with the experimental results (mean \( r = 0.997 \)) and had randomly distributed residuals. Twenty-two subjects performed a series of running sessions at constant speed to establish the highest working intensities that could be endured without an increase in blood lactate (BLa) - the maximal steady-state workload (MSSW). The observed velocities of MSSW were related to the BLa vs velocity curves from the graded test. The graded submaximal exercise tests yielded mean derivatives from the BLa vs velocity relationship curves equal to 0.089 and 0.083 mM per m.min\(^{-1}\) for the young and senior groups, respectively. The derivatives had moderate inter-individual variations. In reversing the procedure, MSSW was estimated for all of the subjects using a common slope of 0.086. Only small individual variations were found between observed and estimated

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MSSW. The mean BLa value f(x), calculated using exponential functions where x = individual observed MSSW, was 3.0 mM. Thus, for endurance-trained athletes, a BLa accumulation rate of 0.086 mM per m.min⁻¹ or, alternatively, a fixed BLa concentration of 3 mM, is recommended as a predictor of MSSW when analysing the BLa-velocity profiles from a graded submaximal test.

49 The effect of exercise modality on the relationship between ratings of perceived exertion (RPE), blood lactate concentration, oxygen uptake (VO2), and heart rate (HR) was examined in 29 untrained male subjects who completed counterbalanced VO2max/lactate threshold (LT) protocols on a cycle ergometer (CE) and treadmill (TM). Heart rate, VO2, and RPE were determined at power outputs corresponding to LT and fixed blood lactate concentrations (FBLC) of 2.0, 2.5, and 4.0 mM and during maximal exercise. A repeated measures ANOVA indicated that, despite significant differences across exercise modality in HR and VO2 at LT, FBLC, and maximal exercise, no significant differences in RPE were found between exercise modalities during leg exercise. Mean (+/- SD) respective values for overall RPE at LT and FBLC of 2.0 mM, 2.5 mM, 4.0 mM, and max were 10.2 (2.2), 13.1 (2.1), 14.1 (2.3), 15.9 (2.3), and

18.8 (1.3) for the CE and 10.8 (1.9), 13.8 (1.8), 14.6 (1.6), 16.2 (2.6), and 18.5 (1.5) for the TM. It was concluded that exercise modality does not affect the perception of exertion at LT, FBLC, or maximal exercise and that a strong relationship exists between RPE and blood lactate concentrations.

The purposes of this investigation were to determine the validity of critical power (CP) as a measure of the work rate that can be maintained for a very long time without fatigue and to determine whether this corresponded with the maximal lactate steady-state (lass, max). Eight highly trained endurance cyclists (maximal oxygen uptake 74.1 ml.kg-1.min-1, SD 5.3) completed four cycle ergometer tests to exhaustion at pre-determined work rates (360, 425, 480 and 520 W). From these four co-ordinates of work and time to fatigue the regression of work limit on time limit was calculated for each individual (CP). The cyclists were then asked to exercise at their CP for 30 min. If CP could not be maintained, the resistance was reduced minimally to allow the subject to complete the test and maintain a blood lactate plateau. Capillary blood was sampled at 0, 5, 10, 20 and 30 min into exercise for the analysis of lactate. Six of the eight cyclists were unable to maintain CP for 30 min without fatigue. In these subjects, the mean power attained was 6.4% below that estimated.

triphosphate, creatine phosphokinase, glycogen) cues highlighted in these studies demonstrate both the complexity of effort perception, and the need for better understanding of the physiological components upon which it is based. Athletes have been shown to have a greater tendency to reduce perceptual ratings than their non-active counterparts. In view of these observations, it is apparent that a theoretical framework based upon physiological and psychological considerations may exist to support the concept of training-induced alterations in perceived exertion. This appears to be particularly true in higher ranges of exercise intensity. Part of the problem in reaching a conclusion on the issue of perceptual ratings trainability centres upon the agreement on what should be recognised as a significant decrement in perceived exertion. It is concluded that there is considerable variation in the findings of the literature and that any reported variations in performance may well be greatly influenced by intersubject variability, the type of exercise, and nutritional status of subject. Further research is required to understand this issue better.