The Relationships Between Lactate Thresholds and Recovery Capacity with Yo-Yo Tests in Soccer Players

Futbolcularda Yo-Yo Testleri ile Laktat Eşikleri ve Toparlanma Kapasitesi Arasındaki İlişkiler

Nermin ÖZAK ÖZKOL,[a]
Faruk TURGAY,[b]
S. Rana VAROL,[b]
Mehmet Zeki ÖZKOL,[b]
Faik VURAL,[b]
Tolga AKŞİT[b]

[a]Ege University, Health Sciences Institute,
[b]Ege University School of Physical Education and Sports, İzmir

Geliş Tarihi/*Received:* 13.02.2012
Kabul Tarihi/*Accepted:* 20.06.2012

This study was presented at 11th International Sport Sciences Congress, 10-12 November 2010, Antalya, Turkey.

Yazışma Adresi/*Correspondence:*
Mehmet Zeki ÖZKOL
Ege University School of Physical Education and Sports, İzmir, TÜRKİYE/TURKEY
zeki.ozkol@ege.edu.tr

ABSTRACT Objective: The aim of the present study was to investigate the relations between the Yo-yo intermittent endurance and recovery performance tests with aerobic and anaerobic threshold speed, lactate and heart rate recovery speed, and whether these tests could be used as an alternative test to describe the lactate thresholds in professional soccer players. **Material and Methods:** 17 male soccer players (aged; 21.11±2.08 year, height; 176.76±6.29 cm, body weight; 72.17±6.72 kg, BMI; 23.09±1.56 kg/m^2) of a third professional soccer league team participated in this study. The thresholds and recovery tests, included an incremental intermittent running stages to the voluntary fatigue and 15 minutes passive recovery afterwards. During this test, heart rate and blood lactate values obtained from fingertip were determined after each running stage and recovery period. By these measurements aerobic and anaerobic threshold running speeds (at 2 and 4 mM blood lactate concentration) were determined. After the end of maximal effort, blood lactate concentration, lactate recovery speed and heart rate recovery speeds were calculated. After above mentioned test, each of the Yo-yo intermittent endurance and recovery tests in level 2 were performed. The significance level was set at $p<0.05$. **Results:** High level correlation was found between the Yo-yo intermittent endurance and recovery performances ($r=0.751$, $p=0.001$). Significant relationships was found between the Yo-yo recovery performance with aerobic threshold speed ($r=0.534$, $p=0.027$), and anaerobic threshold speed ($r=0.550$, $p=0.021$). There were also relationships between the both threshold speeds and the Yo-yo intermittent endurance performance, but it was not significant. There were no significant relations between lactate threshold speeds with heart rate recovery and lactate recovery speeds. **Conclusion:** These results suggest that, the Yo-yo intermittent recovery test (level 2) can be used as an alternative to lactate threshold tests in professional soccer players.

Key Words: Yo-yo intermittent endurance test; yo-yo intermittent recovery test; aerobic threshold; anaerobic threshold; lactate clearance speed; heart rate recovery speed

ÖZET Amaç: Bu çalışmada aerobik ve anaerobik eşik hızı, kan laktat toparlanma hızı, nabız toparlanma hızı ile Yo-yo aralıklı endurans ve toparlanma performans testleri arasındaki ilişkilerin ve bu testlerin futbolcularda laktat eşiklerinin belirlenmesinde alternatif testler olarak kullanılabilirliğinin araştırılması amaçlanmıştır. **Gereç ve Yöntemler:** Çalışmaya 3. profesyonel lig takımlarına mensup 17 erkek futbolcu (yaş; 21,11±2,08 yıl, boy; 176,76±6,29 cm, vücut ağırlığı; 72,17±6,72 kg, VKİ; 23,09±1,56 kg/m^2) katılmıştır. Gönüllüler istemli yorgunluğa kadar devam eden aralıklı koşu ve sonrasında 15 dk süren pasif toparlanmanın olduğu egzersiz testini gerçekleştirdiler. Test esnasında her kademe sonunda ve toparlanma periyodunda; kalp atım hızı ve laktat ölçümü için parmak ucundan alınan kanlardan, aerobik ve anaerobik eşik (2 ve 4 mM kan laktat konsantrasyonuna karşılık gelen) hızları bulundu. Maksimal eforun bitiminden sonra kan laktat konsantrasyonu, laktat toparlanma hızı ve kalp atımı toparlanma hızı hesaplandı. Bu testlerden sonra 2. düzey Yo-yo aralıklı endurans ve toparlanma testleri gerçekleştirildi, anlamlılık için $p<0,05$ değeri temel alındı. **Bulgular:** Yo-yo aralıklı dayanıklılık ve toparlanma testi arasında yüksek düzeyde bir korelasyon bulundu ($r=0,751$, $p=0,001$). Yo-yo aralıklı toparlanma performansı ile aerobik eşik hızı ($r=0,534$, $p=0,027$) ve anaerobik eşik hızı arasında anlamlı ilişkiler bulundu ($r=0,550$, $p=0,021$). Yo-yo aralıklı endurans testi ile aerobik ve anaerobik eşik hızı arasında pozitif korelasyonlar vardı ancak anlamlı değildi. Laktat eşik hızları ile nabız toparlanma hızı ve laktat toparlanma hızı arasında anlamlı bir ilişki bulunmadı. **Sonuç:** Çalışmanın sonuçlarına göre Yo-yo aralıklı toparlanma testi (2. seviye) profesyonel futbolcularda laktat eşik testlerine alternatif test olarak kullanılabilir.

Anahtar Kelimeler: Yo-yo aralıklı endurans testi; yo-yo aralıklı toparlanma testi; aerobik eşik; anaerobik eşik; laktat eliminasyon hızı; nabız toparlanma hızı.

Turkiye Klinikleri J Sports Sci 2012;4(2):55-63

Knowing athletes' physical and physiological profile in any sports discipline is important in terms of planning training programs and therefore performance. There are several available tests to determine the mentioned profile. However, the validity and reliability of employed tests are just as vital. Moreover, these tests need to be economical. So, reliable results depend on tests that correspond with the sports discipline as well as the movement pattern and physiological requirements of the athlete.

Intermittent sports disciplines with high physical requirements like soccer and basketball involve frequently practiced intense activities like jumps, direction changes, high-speed running and sprints. This is why the player's performance during the sports activity depends on his/her capacity to repetitively perform intense exercise. For instance the quality of soccer is related to the amount of high-intensity sprints performed throughout the game.[1,2] This is why players' recovery potential following intense exercise is important in these sports disciplines. This, to a great extent, is related to endurance capacity.

For instance, performance in soccer is closely related to both endurance and recovery capacity because during a game an average distance of 11-13 km is covered-either walking, running or sprinting.[1] High levels of blood lactate levels may typically be observed during a game. Lactic acid may hinder muscle glycolysis speed by inhibiting glycolytic enzyme activity.[3] This is why eliminating lactate from the blood following exercise is important for subsequent performance, especially if ensuing exercises are repetitive and intense. It is important to replenish tissue oxygen reserves during recovery because of a need for high oxygen intake to restore homeostasis by means of processes like creatine phosphate re-synthesis, lactate metabolism and removing intracellular inorganic phosphate, the latter considered as the reason for exhaustion following repetitive sprint exercises.[4] This is why it is quite normal to find a relation between exhaustion during multiple sprints and aerobic fitness.[4] Based on this relation the Yo-yo test has recently gained popularity for being easy to perform and cheap. The Yo-yo intermittent recovery tests are quicker than most fitness tests employed frequently in the science of sports. The Yo-yo intermittent recovery test is important field test that involved soccer-specific movements.[5,6] These tests are prevalent in many team sports in measuring player's capacity to repeat intense exercise for the characteristics of the tests and their simplicity. However, the validity of tests are yet to be fully proven.

The Yo-yo test is a performance test featuring diverse sprint levels and various recovery times. On the other hand, as is known, lactate elimination reflects increased muscular lactate transport capacity, oxidative capacity, declined glycogenolysis as well as increased hepatic capacity. This is why endurance performance can be predicted from the relation between exercise intensity and plasma lactate.[7] Maximal oxygen consumption ($maxVO_2$) is used as an indicator for aerobic power.[8] Determination of anaerobic threshold is an important measure of aerobic endurance.[8,9] However, recently in soccer $maxVO_2$ is largely replaced by aerobic threshold (AT, exercise load corresponding to 2 mM blood lactate) and anaerobic threshold (AnT, exercise load corresponding to 4 mM blood lactate) as criteria for aerobic endurance, the ideal training loads (intensity and duration) for development and monitoring progress in endurance performance.[8,10-12] A statistically significant relation has been found between endurance level and maximum lactate elimination. Hence, maximum lactate elimination can be used to express a player's endurance level.[13]

Actually, the mentioned threshold concepts physiologically entail notions like oxygen use at lactate threshold and mechanical efficiency.[14] Aerobic capacity is an important factor in elimination of lactate in blood both during and after exercise.[14] The validity and reliability of lactate threshold tests performed based on lactate metabolism is proven.[8,12,14,15] However we have not come across a study in literature that investigates relations between the Yo-yo tests and those tests used as the golden standard based on certain metabolic foundations like AnT and lactate elimination and heart rate recovery speed (HrRS, pulse/min).[8,13,14,16,17]

The purpose of the present study was to investigate relations between the Yo-yo intermittent endurance and recovery performance tests with aerobic and anaerobic threshold speed, lactate and heart rate recovery speed, and whether the Yo-yo tests could be used as an alternative test to describe the lactate thresholds in professional soccer players.

MATERIAL AND METHODS

SUBJECTS

Volunteers were subject to anaerobic threshold test (AnTT) immediately followed by a recovery (lactate and heart rate recovery) test with additional 2nd level the Yo-yo intermittent endurance and the Yo-yo intermittent recovery tests applied to trained players with at least two days apart but at the same time of the day. All tests were carried out at an artificial turf pitch. AnTT exercise tests were performed on 5-6 person groups between 9 AM and 12 PM.

Subjects voluntarily participating the study were, on a specified date, informed about the purpose and benefits of the study, the tests to be performed and potential risks. Approval was obtained by University School of Medicine's Research Ethics Committee. Participants were warned about refraining from carrying out heavy exercise at least two days before the measurements indicated below.

25 active male soccer players from a third professional soccer league team participated in this study. However only data from 17 players (aged; 21.11±2.08 years, height; 176.76±6.29 cm, weight; 72.17±6.72 kg, BMI; 23.09±1.56 kg/m^2) that participated all tests were included in the scope of the study.

EXPERIMENTAL PROCEDURES

Anaerobic Threshold Test

Test protocol: Following a standard warm-up the exercise program started at 8 km/h speed with each stage lasting 5 minutes and a 1.2 km/h increase in speed at the end of each stage with a 1 minute passive resting break between stages until voluntary exhaustion.[15] A 15-minute passive recovery period was allocated at the end of the test. The subjects were allowed to drink water during the test.

Volunteers were positioned at each 20 m starting point within a 40 m long and 20 m wide rectangle, running at a pace dictated by a sound system. Running speed was monitored with a sound system giving out a signal every 20 m. Subjects continue the test if they miss the first signal but make it to the second one. The test is terminated if participant misses two consecutive signals, in other words, if he has become too exhausted to keep up with the pace. Test continues for about 6-7 stages (Figure 1, Table 1).

Heart rate (HR) was read at the end of each stage (with Polar RS 400) and blood sample collected for measuring lactate levels. Blood lactate (total lactate) measurements were carried out with YSI 1500 SPORT model lactate analyzer (Manufacturer: Yellow Springs Instruments Corp.). AT and AnT speeds (as km/h) were calculated from the speed/lactate graph performing interpolation or extrapolation.

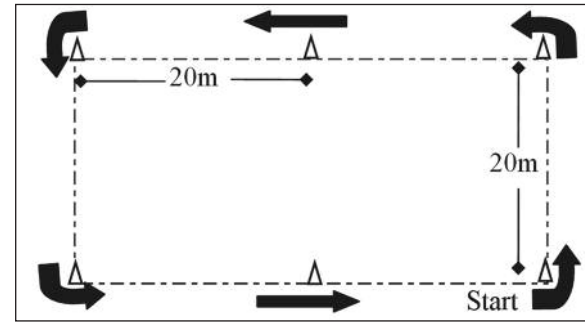

FIGURE 1: Design of the anaerobic threshold test.

TABLE 1: Procedure of anaerobic threshold test.

Stage	Running speeds (km/h) of stages	Running duration (min) of stages	Resting time (min) between stages
1	8.0	5	1
2	9.2	5	1
3	10.4	5	1
4	11.6	5	1
5	12.8	5	1
6	14.0	5	1
7	15.2	5	1

Calculating AT and AnT Speeds

HR and lactate values measured at the end of each stage were placed on the graph corresponding to the speed at that specific stage. The speed corresponding to the 2 mM lactate value was named aerobic threshold speed (ATS), the pulse corresponding to this speed was named (ATHR); whilst the speed corresponding to the 4 mM lactate value was named anaerobic threshold speed (AnTS) and the pulse corresponding to this speed was named (AnTHR).[12]

Recovery Test

The recovery test was performed during the passive recovery period following the AnTT exercise conducted to determine AT and AnT. At the end of the exercise, lactate value 3 minutes after the end of maximal effort was named maximal lactate (MLA) whilst the value at the end of 15 minutes was named (15MinLa). Lactate recovery (elimination) speed (LaRS, mM/min) was calculated by dividing the difference between two lactate values by elapsed time (12 min). On the other hand, maximal heart rate recorded immediately after exercise was named (MHR) whilst pulse 3 minutes later was named (3MinHR). Heart rate recovery speed was calculated by dividing the difference between the two values by three. Respective the Yo-yo tests were performed 3 days after this test.

The Yo-yo Intermittent Recovery Test

Beginning from the start-point, the course was designed to mark out three lines using cones with 5 m between the 1st and 2nd and 20 m between the 2nd and 3rd lines. Groups were formed to perform the test with athletes standing 2 meters apart. Athletes were subject to a shuttle run between 20 m cones that gradually increased in pace until maximal level. A 10 second recovery period of jogging was included after each shuttle run.[6]

The Yo-yo Intermittent Endurance Test

Beginning from the start-point the course was designed to mark out three lines using cones with 2.5 m between the 1st and 2nd and 20 m between the 2nd and 3rd lines. Athletes were subject to a shuttle run between 20 m cones that gradually increased in pace until maximal level. A 5 second recovery period of jogging was included after each shuttle run. Depending on soccer players' fitness level tests lasted between 5 to 20 minutes. Each of the Yo-yo test consists 2 levels. The 2nd level of the Yo-yo test was employed, as soccer players were the trained group. Score forms prepared for each test were used to determine the number of covered runs and speed for each athlete. Covered "distance" was taken as basis for performance.[18]

LACTIC ACID ANALYSES

In order to perform the lactic acid analysis, the fingertip was first wiped with alcohol and then dried with a piece of cotton wool. Next, the fingertip was pierced with a lancet and squeezed gently. For each subject blood was collected in two hematocrit capillary tubes with heparin and later transferred into blood lactate preserving tubes of the YSI 1500 lactate analyzer employed for the tests before getting mixed. Samples were stored in a refrigerator until analysis commenced. Lactate preserving tubes of the lactate analyzer prevent glycolysis in whole blood samples for 1-2 days, therefore lactate samples were analyzed the same day using the YSI 1500 lactate analyzer. The daily calibration of the analyzer was carried out with 5 and 15 mM standard lactate calibration solution. 5 mM standard calibration solution was used for analyzer calibration prior to measuring each of the subject's samples. A lactate membrane, a tampon to prepare reactive substance, and erythrocyte breaking lysing agent was used during measurements with the device. Blood lactate levels were analyzed using blood samples collected from the fingertip of each subject. Results were presented in mM.

MEASURING HEART RATE

The heart rate monitor (Polar RS 400; Electro Oy, Kempele, Finland) was used to measure heart rate during the tests. Real time heart rate was sent to the monitor from the chest strap by radio waves. Heart rate was constantly monitored throughout the process.

STATISTICAL DATA ANALYSES

Average and standard deviation was used in the numeric presentation of data. Kolmogorov-Smirnov test was performed to verify whether data distribution

TABLE 2: The results of AT & AnT and recovery test (lactate and heart rate), n=17.

ATS (km/h)	ATHR (pulse/min)	AnTS (km/h)	AnTHR (pulse/min)	MHR (pulse/min)	3MinHR (pulse/min)	HrRS (pulse/min)	MLa (mM)	15MinLa (mM)	LaRS (mM/min)
9.78±0.82	160.35±7.93	11.83±1.14	177.64±5.57	198.17±9.51	131.47±12.66	22.23±3.77	9.08±2.27	6.25±2.42	0.23±0.05

Data expressed as mean±SD.

ATS: Aerobic threshold speed; ATHR: Aerobic threshold heart rate; AnTS: Anaerobic threshold speed; AnTHR: Anaerobic threshold heart rate; MHR: Maximal heart rate (HR immediately after AnTT); 3MinHR: HR 3 minutes after end of AnTT; HrRS: Heart rate recovery speed [(MHR- 3MinHR)/3]; MLa: Lactate value 3 minutes after AnTT; 15MinLa: Lactate value 15 minutes after AnTT; LaRS: Lactate recovery speed [(MLa-15MinLa)/12].

was normal. Levene's test was performed to verify homogeneity amongst the groups. Normal distribution and homogeneity tests verified that data distribution was normal and that groups were homogenous. Parametric analysis methods were used. "Pearson r" correlation analysis was used for relations between aerobic and anaerobic threshold speed and distances covered during the Yo-yo tests, as well as the relations between distances covered during the Yo-yo tests and lactate elimination speed and heart rate recovery. SPSS 11.0 statistics program (SPSS Inc., Chicago, IL) was used for data analysis. The $p<0.05$ values was accepted as indicator of significance.

RESULTS

MHR=198.17 pulse/min and MLA= 9.08 mM values found at the end of threshold test shows that the test was carried out in a maximum levels.

Table 2 presents soccer players' aerobic & anaerobic threshold and recovery test performance.

Figure 2 presents soccer players' Yo-yo tests performance.

Significant correlation did not emerge between the Yo-yo intermittent endurance performance with AT & AnT values and recovery performance (Table 3).

A significant positive correlation was found between the Yo-yo intermittent recovery test performance and ATS (km/h), AnTS (km/h). Significant correlations did not emerge between the Yo-yo intermittent recovery performance and recovery data (Table 4).

A significant positive correlation was found between the Yo-yo intermittent endurance and the Yo-yo intermittent recovery performance (r=0.751, p=0.001).

Significant correlations were found between ATS and ATHR (r=0.934, p=0.000) and between AnTS and AnTHR (r=0.555, p=0.021). Additionally,

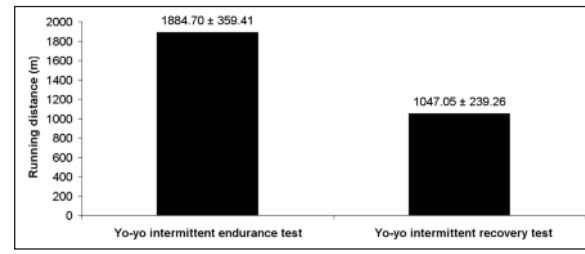

FIGURE 2: Soccer players' Yo-yo intermittent endurance and recovery test performance results.

TABLE 3: Correlations between the Yo-yo intermittent endurance performance and AT & AnT values and recovery test (lactate and heart rate) results.

Variables	r	p
YYIEP-ATS (km/h)	0.458	0.065
YYIEP-ATHR (pulse/min)	-	0.181
YYIEP-AnTS (km/h)	0.461	0.062
YYIEP-AnTHR (pulse/min)	-	0.320
YYIEP-MHR (pulse/min)	-	0.904
YYIEP-3MinHR (pulse/min)	-	0.953
YYIEP-HrRS (recovery/min)	-	0.971
YYIEP-MLa (mM)	-	0.972
YYIEP-15MinLa (mM)	-	0.925
YYIEP-LaRS (mM/min)	-	0.854

YYIEP: Yo-yo intermittent endurance performance; ATS: Aerobic threshold speed; ATHR: Aerobic threshold heart rate; AnTS: Anaerobic threshold speed; AnTHR: Anaerobic threshold heart rate; MHR: Maximal heart rate immediately after AnT Test; 3MinHR: HR 3 minutes after end of AnT Test; HrRS: HR recovery speed [(MHR- 3MinHR)/3]; MLa: Maximal lactate value 3 minutes after AnT Test; 15MinLA: Lactate value 15 minutes after AnT Test; LaRS: Lactate recovery speed [(MLa-15MinLa)/12].

TABLE 4: Correlation between the Yo-yo intermittent recovery performance and AT & AnT values and recovery test (lactate and heart rate) results.

Variables	r	p
YYIRP-ATS (km/h)	0.534	0.027
YYIRP-ATHR (pulse/min)	-	0.241
YYIRP-AnTS (km/h)	0.550	0.021
YYIRP-AnTHR (pulse/min)	-	0.862
YYIRP-MHR (pulse/min)	-	0.477
YYIRP-3MinHR (pulse/min)	-	0.520
YYIRP-HrRS (recovery/min)	-	0.902
YYIRP-MLa (mM)	-	0.840
YYIRP-15MinLa (mM)	-	0.891
YYIRP-LaRS (mM/min)	-	0.844

YYIRP: Yo-yo intermittent recovery performance; ATS: Aerobic threshold speed; ATHR: Aerobic threshold heart rate; AnTS: Anaerobic threshold speed; AnTHR: Anaerobic threshold heart rate; MHR: Maximal heart rate immediately after AnT Test; 3MinHR: HR 3 minutes after end of AnT Test; HrRS: HR recovery speed [(MHR- 3MinHR)/3]; MLa: Maximal lactate value 3 minutes after AnT Test; 15MinLA: Lactate value 15 minutes after AnT Test; LaRS: Lactate recovery speed [(MLa-15MinLa)/12].

the high correlation found between ATS and AnTS (r=0.809, p=0.000).

The insignificantly negative correlations were found between lactate recovery speed (LaRS) and heart rate recovery speed (HrRS) (r=-0.170, p=0.515). A significant negative relationship was found between HrRS and HR value (3MinHR) 3 minutes after recovery test (r= -0.690, p=0.002). Moreover, significantly negative correlations were found between AnTS and MLA (r=-0.710, p=0.001) as well as 15MinLa (r=-0.694, p=0.002).

DISCUSSION

This study investigated the relations between lactate thresholds (ATS, AnTS) and the Yo-yo intermittent endurance and recovery tests.

The significant correlations were found between ATS and ATHR, and between AnTS and AnTHR. These relations demonstrate that HR values can be used in endurance training instead of the mentioned threshold speeds. High degree of correlations found between ATS and AnTS, not only demonstrate that ATS and AnTS values can be used in determining endurance levels, they also show that these speeds or corresponding heart rate values can be used as exercise loads in endurance training.

The Yo-yo intermittent endurance (YYIEP) and recovery performance (YYIRP) (in level 2) respectively was 1884.70 m and 1047.05 m in this study. It was found that the aerobic loading approached maximal values and the anaerobic energy system was highly taxed during the Yo-yo intermittent recovery level 2 test, and there was a valid measure of fitness performance in soccer in that study.[19] MHR=198.17 pulse/min and MLA= 9.08 mM values found at the end of threshold test in this study shows that the test was carried in a maximum levels. The results of recovery test in this study were similar with the results of Krustrup et al. Amongst examined parameters the only significant relations were found between the Yo-yo recovery performance with ATS and AnTS. In addition to, it was found significant relationship between the Yo-yo endurance and recovery performance in this this study. Therefore this results suggest that, the Yo-yo intermittent recovery tests in level 2 can be used as an alternative to lactate threshold tests (ATS and AnTS) in professional soccer players. Furtermore these findings verify that ATS and AnTS values used in this study can also be used in determining recovery levels in soccer players.

There were also the relationships between the both threshold speeds (ATS and AnTS) and the yo-yo intermittent endurance, but it was not significantly in this study. In other study; it was determined that the YYIEP (in level 2) test results were significantly related to maxVO_2, VO_2 and speed at ventilatory threshold (VT) in soccer players and YYIEP can be considered an aerobic fitness-related field test.[20] In the difference in these two studies may be in particular, role of the factors as the performance levels and/or training status of the soccer players and study design used in this study.

Lactate concentrations in humans at resting state remains at low levels only increasing slightly during moderate level exercise. This is because production is compensated by lactate oxidation (using lactate to generate aerobic energy) and gluconeogenesis (using lactate or other material to regener-

ate glycogen).[7] When exercise level increases, this equilibrium impairs and lactate increase in blood.[7,13,15] There are two typical breakpoints that are passed during incremental exercise: the intensity at which blood lactate begin to rise above baseline levels and the highest intensity at which lactate production and elimination are in equilibrium (maximal lactate steady state [MLSS]). It is named also that the load intensity at first breakpoint as aerobic threshold and the load intensity at second breakpoint as anaerobic threshold.[8,15]

Lactate elimination speed and heart rate recovery speed capacities are related to aerobic capacity.[8,13] Studies have shown that endurance training develops lactate elimination capacity.[21]

Moreover, there is a relation between lactate elimination and aerobic endurance levels.[13]

Statistically significant relation presented between endurans level and maximum lactate elimination can shows, why maximum lactate elimination can be used to express an athlete's level of endurance.[13] But the negative relationships between lactate threshold speeds and HrRS and LaRS were insignificant.

The significantly negative correlations found between AnTS with MLA and 15MinLa demonstrate the close relation between AnTS and lactate metabolism. These findings can demonstrate the presence of an indirect relation between LaRS and anaerobic threshold speed (AnTS). However, these latter relations are inexistent with ATS. This is possibly because ATS is predominantly based on more aerobic metabolism rather than lactate metabolism such as AnTS. Nonetheless the findings found in this study may reflect the expected basic relation between recovery and endurance capacity. Furthermore, the relationship identified between HrRS and 3MinHR similarly demonstrate that these tests have a metabolic basis.

A study conducted on males of different training levels with an average age of 26.2 years found a relationship between maximum muscular oxidative capacity and blood lactate elimination capacity following a 1 minute long supramaximal exercise amongst well-trained individuals.[22]

Aerobic capacity is an important factor in the elimination of blood lactate both during and after the exercise.[13] Increased blood circulation in muscles (an important lactate consumer during recovery) as well as the liver, heart and kidneys, which all play an important role in lactate metabolism, together with increased substrate and hormone transport may render recovery more effective.[13,23]

Muscle elimination depends on lactate concentration, muscle fibre type and the athletes fitness level.[7] A large portion of lactate accumulating in the blood is taken up by skeletal muscle and later metabolized.[3,7,13] It is important to replenish tissue oxygen reserves during recovery because CP resynthesis needs high oxygen intake to restore homeostasis following repetitive sprint exercises.[19,22] This is why it is normal to find anticipated relationship between the Yo-yo endurance and recovery performance values as well as between endurance and recovery performances following multiple sprints and lactate threshold values, also used as an indicator of aerobic fitness in this study. Hence, these correlations found in these tests demonstrate the validity of the these tests.

This study was unable to determine a significant relation between HrRS and lactate threshold values or the Yo-yo tests. But the significant negative relationship was found between HrRS and 3MinHR in this study. Measuring HR recovery following exercise is the most popular method in evaluating heart-circulation and respiration system functions in the fields of both exercise and medicine.[8,16] It was found that HR recovery following high intensity exercise is quicker in athlete with greater aerobic capacity.[16] HR increased during exercise will quickly start to fall to normal resting values once exercise is finished. It is stated that HR recovery after maximal exercise is mediated by intrinsic, nervous and humoral factors.[17] It is stated that HR recovery during the 1st minute after submaximal exercise between maxVO_2 between 40-65% could basically result from vagal nerve tone restoration.[16] Sympathetic nerve or humoral factor regression is though to account for further decline of HR to resting values.

It has been observed that HR recovery becomes faster at the end of an eight-week aerobic exercise workout and that the duration extended significantly after a two week gap without exercise, with a return to basal values following a 2 week sedentary life style. Moreover, a negative relation was found between HR recovery within the first 30 seconds after exercise and pre-exercise levels.[16] These findings suggest that HR recovery improves with exercise workout and that individuals with weaker recovery will benefit more from exercise workout. Another study exists demonstrating HR recovery improvement following a 9-week aerobic exercise workout.[24] This is why extended HR recovery immediately after exercise, and especially within the first 30 seconds is connected to a rise in sympathetic nerve activity and (or) accumulation of anaerobic metabolites that can weaken vagal nerve effect, reactivated after exercise.[16] Aerobic exercise workout will decrease resting HR value and shorten post-exercise recovery phase.[25,26] It is stated that these changes arise from increased vagal tone and fast vagal reactivation after the completion of exercise.[25]

Making measurements at the start of the season could be the reason behind finding insignificant relations between HrRS and LaRS, and lactate thresholds. In other words, the fact that training levels being far from effecting these relations may be playing a role. Thus, number of participants and study design may also have played a role.

CONCLUSION

Based on direct or indirect measurement methods, various tests have been developed to determine lactate threshold values in professional athletes. Direct methods offer greater measurement sensitivity, which is tremendously important in exposing professional athletes' personal performance values. However, present study on the Yo-yo intermittent recovery tests found significant relations with lactate threshold tests. Being both straightforward and economical to perform, the Yo-yo intermittent recovery test could be used as an alternative in establishing lactate threshold values. The number of participants in this study was limited; henceforth repeating the tests with more participants following a 2-3 month training period may offer more reliable results. This results suggest that, the Yo-yo intermittent recovery level 2 test can be used as an alternative to lactate threshold tests in professional soccer players.

Acknowledgements

The authors would like to express their gratitude to the professional soccer players who participated in the study and to the head coach, assistant coaches and club officials for their assistance in the organization of the testing sessions.

REFERENCES

1. Bangsbo J, Nørregaard L, Thorsø F. Activity profile of competition soccer. Can J Sport Sci 1991;16(2):110-6.
2. Mohr M, Bangsbo J. Development of fatigue towards the end of a high level soccer match. Med Sci Sports Exerc 2001;33(5):160.
3. Ahmaidi S, Granier P, Taoutaou Z, Mercier J, Dubouchaud H, Prefaut C. Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. Med Sci Sports Exerc 1996;28(4): 450-6.
4. Bangsbo J. The physiology of soccer--with special reference to intense intermittent exercise. Acta Physiol Scand Suppl 1994;619:1-155.
5. Köklü Y, Özkan A, Ersöz G. [Assesment and improvement of endurance performance in soccer]. Celal Bayar University J Physical Edu Sports Sciences 2009;4(3):142-50.
6. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. Sports Med 2008;38(1):37-51.
7. Stallknecht B, Vissing J, Galbo H. Lactate production and clearance in exercise. Effects of training. A mini-review. Scand J Med Sci Sports 1998;8(3):127-31.
8. Heck H, Mader A, Hess G, Mücke S, Müller R, Hollmann W. Justification of the 4-mmol/l lactate threshold. Int J Sports Med 1985;6(3): 117-30.
9. Akça F, Akalan C, Koz M, Ersöz G. [Anaerobic threshold in rowing: Relationship of ventilatory and lactate threshold]. Turkiye Klinikleri J Sports Sci 2010;2(1):7-12.
10. Föhrenbach R, Buschmann J, Liesen H, Hollmann W, Mader A. [Speed and endurance in soccer players of various sport classes]. Schweiz Z Sportmed 1986;34(3):113-9.
11. Alemdaroğlu U, Dündar U, Köklü Y. [Comparison of the conconi test performance of soccer players according to playing position and league level]. Celal Bayar University J Physical Edu Sports Sciences 2010;5(1):15-20.

12. Kindermann W, Simon G, Keul J. The significance of the aerobic-anaerobic transition for the determination of work load intensities during endurance training. Eur J Appl Physiol Occup Physiol 1979;42(1):25-34.
13. Francaux MA, Jacqmin PA, Sturbois XG. The maximum lactate clearance: a new concept to approach the endurance level of an athlete. Arch Int Physiol Biochim Biophys 1993;101(1): 57-61.
14. Coyle EF. Integration of the physiological factors determining endurance performance ability. Exerc Sport Sci Rev 1995;23:25-63.
15. Borch KW, Ingjer F, Larsen S, Tomten SE. Rate of accumulation of blood lactate during graded exercise as a predictor of 'anaerobic threshold'. J Sports Sci 1993;11(1):49-55.
16. Sugawara J, Murakami H, Maeda S, Kuno S, Matsuda M. Change in post-exercise vagal reactivation with exercise training and detraining in young men. Eur J Appl Physiol 2001;85(3-4):259-63.
17. Savin WM, Davidson DM, Haskell WL. Autonomic contribution to heart rate recovery from exercise in humans. J Appl Physiol 1982;53 (6):1572-5.
18. Bradley PS, Mohr M, Bendiksen M, Randers MB, Flindt M, Barnes C, et al. Sub-maximal and maximal Yo-Yo intermittent endurance test level 2: heart rate response, reproducibility and application to elite soccer. Eur J Appl Physiol 2011;111(6):969-78.
19. Krustrup P, Mohr M, Nybo L, Jensen JM, Nielsen JJ, Bangsbo J. The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. Med Sci Sports Exerc 2006;38(9):1666-73.
20. Castagna C, Impellizzeri FM, Chamari K, Carlomagno D, Rampinini E. Aerobic fitness and yo-yo continuous and intermittent tests performances in soccer players: a correlation study. J Strength Cond Res 2006;20(2): 320-5.
21. Juel C, Holten MK, Dela F. Effects of strength training on muscle lactate release and MCT1 and MCT4 content in healthy and type 2 diabetic humans. J Physiol 2004;556(Pt 1):297-304.
22. Thomas C, Sirvent P, Perrey S, Raynaud E, Mercier J. Relationships between maximal muscle oxidative capacity and blood lactate removal after supramaximal exercise and fatigue indexes in humans. J Appl Physiol 2004;97(6):2132-8.
23. Freund H, Zouloumian P. Lactate after exercise in man: I. Evolution kinetics in arterial blood. Eur J Appl Physiol Occup Physiol 1981;46(2):121-33.
24. Hagberg JM, Hickson RC, Ehsani AA, Holloszy JO. Faster adjustment to and recovery from submaximal exercise in the trained state. J Appl Physiol 1980;48(2):218-24.
25. Yamamoto K, Miyachi M, Saitoh T, Yoshioka A, Onodera S. Effects of endurance training on resting and post-exercise cardiac autonomic control. Med Sci Sports Exerc 2001;33(9):1496-502.
26. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, et al. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol 1994;24(6):1529-35.