Module 3: Endurance Assessment in Team Sports

UNIT 3.1 Assessment of Aerobic and Anaerobic Physical Condition in Athletes

3.1.1 Objectives for the Assessment of Endurance in Sports

According to Vargas (2008), the assessment process can be summed up in the following key aspects:

1. Diagnosis: Determine the current level of fitness of the subjects being tested in order to begin working on specific areas.
2. Detection of dysfunction: when the results of a certain test are different from those expected, we are in the presence of a "difficulty."
3. Selection: once we have a profile for the athletes being tested, we can use existing tables to place them in groups with similar characteristics.
4. Planning: once we understand the individual abilities of an athlete, we can create a personalized training program.
5. Prediction: in certain circumstances we can chart the possible goals an athlete could reach through a training program.
6. Control: we can also use this information to quantify an athlete's evolution, thereby obtaining both an athlete's strong points and weak points.
7. Motivation: the different results obtained through the tests can help us identify positive elements, which can then be used as motivation for achieving a variety of objectives.

3.1.2 Types of Assessment

Despite the opinions of some authors who insist on the validity of subjective assessment derived solely from professional experience, we propose that it is also necessary to familiarize ourselves with objective assessments; these use measurements from specific techniques and processes which have been developed through scientific research (Vargas, 2008).

From this point on, we will call these techniques *tests*. Sport Tests are scientifically designed to measure specific physical qualities with a certain percentage of reliability (Vargas, 2008). They are the result of detailed scientific studies on the human response to specific stimuli. These studies involve a long process of investigation which includes defining the problem and creating a hypothesis, reviewing current literature, lab studies under stress conditions, correlations between lab and field studies, reporting and consideration of final conclusions, and discussions between internationally recognized scientific authorities, etc. (Vargas, 2008).

Due to the current demands of field sports (soccer, rugby, hockey, basketball etc.), athletes require a range of highly developed motor skills, such as aerobic and anaerobic strength, power and endurance (Dupont, Akakpo, & Berthoin, 2004, Helegrund et al., 2001), in other words, physical qualities necessary for these games. In order to develop these parameters in the best way possible, training intensity should be developed according to an athlete's individual capabilities (Vargas, 2008).

We must approach a point where technical staff understand endurance in team sports as: "The ability to endure and adapt to the physical, technical and tactical demands established by a specific game structure during the encounter and throughout the whole competition" (Masafret, 1998).

3.1.3 Test Classifications

In order to understand endurance tests more fully, they must be classified and contextualized in the following way (Massafret, 1998):

- General endurance.
- Specific endurance:
  - Technical endurance.
  - Decision-making endurance.
  - Endurance to the structure of the game or competition.

From here on, the types of test differ.

In cyclic sports, endurance is understood to be a physical and physiological quality, where the player is considered to be the only one responsible for performance, and performance and physical-physiological quality are intricately linked. Different authors (García Manso, Ruiz Caballero, Navarro Valdivielso, 1996) use different taxonomies according to the following criteria:

- In relation to the duration of the effort:
  - Short-term endurance.
  - Medium-term endurance.
  - Long-term endurance.

- In relation to the number of muscle groups involved:

    - General endurance.
    - Local endurance.

- In relation to the predominant energy system:

    - Aerobic endurance.
    - Anaerobic lactic endurance.
    - Anaerobic alactic endurance.

- In relation to relationship between different qualities:

    - Strength endurance.
    - Speed endurance.

- In relation to how muscles operate:

    - Static endurance.
    - Dynamic endurance.

- In relation to the level of specificity:

    - General endurance.
    - Specific endurance.

Endurance in acyclic sports should be understood as: "The ability to endure and adapt to the physical, technical and tactical demands established by a specific game structure during the encounter and throughout the whole competition" (Masafret, 1998). Thus the following are important:

1. The role of the player within the game structure.
2. The characteristics of the game structure.
3. The type of direct adversary.

From here, adaptations can be made according to the needs of each sport, and a different type of classification can be established:

1) **General endurance:** Basically made up of the bioenergetic structure of human beings, in addition to coordination, cognition, conditioning and socio-affective aspects (Massafret, 1998).

    a. **Bioenergetic structure:** This is responsible for supplying the energy needed for human beings to perform in different situations.
    b. **Coordinating structure:** This is responsible for supporting the diversity of technical movements required by the discipline.
    c. **Cognitive structure:** This is not very specific but is always present in every situation. To train this skill the athlete does not need to make decisions.

d. **Conditional structure:** This is responsible for providing muscular and energetic support to human beings while they are carrying out activities. Depending on the orientation of the preferential simulated situation, this structure can be very specific or quite general.
e. **Socio-affective structure:** Endurance training is usually carried out on an individual basis. However, some preferential simulated situations can develop nonspecific player communication.

2) Specific endurance:

a. Technical endurance:

Specific in nature, developing individual technical contents which have become automatic, with unspecific decision-making. This aims to optimize the coordinating structure in different states of fatigue (Massafret, 1988).

1. Coordinating structure: Specific, has varying level of specificity and difficulty. Movement with or without the ball.

2. Conditional structure: Collective, involves all the different manifestations of endurance in the sport played. Integrated participation of the energy systems.

3. Cognitive structure: Low level of specificity, made up of individual tactics where decision-making is not based on the structure of the game, but on improving general, individual aspects: trajectories which imply specific trajectories of teammates; the general capacity to anticipate when faced with actions which have no relation to the game structure.

4. Socio-affective structure: These will normally be individually oriented situations, which often encourage aspects that favor communication between teammates.

b. Decision-making endurance:

Specific in nature, where decision-making is specific and is related to the game structure. Its main goal is to optimize cognitive structure in different states of fatigue.

1. Coordinating structure: Specific and complex in nature due to the technical necessities of developing preferential simulated situations and tactical planning. This aims to combine a variety of technical elements in order to solve the different situations.

2. Conditional structure: Specific in nature, makes it possible to resolve the demands of the game itself by combining these necessities randomly and in an integrated way.

3. Cognitive structure: Highly specific in nature, where players must solve different preferential simulated situations the most efficient way possible based on the game structure. Automation, concrete tactical situations, (set plays after regaining possession, typical marking situations, etc.

4. Socio-affective structure: Highly specific in nature, where relationships between players are built around the necessities of the game structure. The level of competitiveness of these situations is not very high.

c. Endurance to competition:

Seek the best synergy of coordination and participation between all of the structures so players can solve competitive situations in order to optimize the game structure (Massafret, 1988).

1. Coordinating structure: maximum level of specificity, difficulty level appropriate for competition. The use of different technical elements related to the needs of competition and game structure.

2. Conditional structure: maximum level of specificity. Integrated participation of the energy systems related to the game structure and competition.

3. Cognitive structure: maximum level of specificity, the development of the game structure is based on the characteristics of opponents.

4. Socio-affective structure: maximum degree of cooperation and cohesion. High level of competitiveness.

The objectives, according to the definition of endurance corresponding to sports with changing situations, will be:

a. Resist tiredness, fatigue and bioenergetic, conditional and cognitive wear caused by the game structure.
b. Optimize a player's performance while executing technical movements and decision-making during the game.
c. Increase the average intensity of the game structure, avoiding temporary periods where there is a loss of control over the game due to fatigue.
d. Accelerate the recovery process during the micro pauses in a game.
e. During the game - during the season: establish a rhythm (number of technical-tactical actions/time) as a way of monitoring and a collective intensity index.

Other criteria are added in order to classify the sports endurance tests, which could help understand the characteristics of these tests.

Direct tests

As indicated by Vargas (2008), direct tests are those which measure a particular physical capacity in a direct way, without the need for mathematical calculations. Direct tests thus allow for more objective and reliable results than indirect tests. For example: measuring VO_2max directly by using a gas analyzer.

Indirect tests

As Vargas (2008) has indicated, indirect tests are those which estimate a particular physical capacity by using mathematical calculations, and which therefore contain more errors than direct tests. For example: Estimating VO_2max via the *Multistage-Fitness Test (Leger, 1982)*. This test has an r=0.90 regarding the VO_2max directly measured through a gas analyzer (automatic) (Vargas, 2008).

Nevertheless, it is worth clarifying that a test is not considered direct or indirect just because it was carried out in the field or in a lab. In fact, today we can directly measure maximal oxygen consumption, for example, in the field by using a telemetric gas analyzer (Vargas, 2008).

In the case of endurance tests, other sports-related classifications include the following:

Cyclical (or lineal) tests

This type of type of test demonstrates motor ability used in running, by maintaining a sequence of movements without changing the direction or the orientation of the movements. These tests can be at a constant speed, where the same speed is maintained throughout the whole test process, or at an incremental speed, where the protocol will determine, through some type of signal (generally auditory, such as sounds or beeps) progressive increases in the running speed throughout the test.

Acyclic tests (with changes of direction)

This type of test demonstrates the ability to accelerate, decelerate, change direction and resume acceleration, by generating changes of direction and orientation in the athlete's movements. As with cyclical tests, these tests can be at a constant speed, where the same speed is maintained throughout the whole test process, or at an incremental speed, where the protocol will determine, through some type of signal (generally auditory, such as sounds or beeps) progressive increases in the running speed throughout the test. In general, these tests are all incremental, like the *Multistage-Fitness Test,* the *Yo-Yo endurance test* or the *30-15 IFT*, which will be described and analyzed later on.

UNIT 3.2 Field Endurance Tests in the Context of Sports

3.2.1 General Endurance Test I

Maximal, indirect cyclical field tests

Cooper Test or 12 Minute Test (Cooper, 1968)

Material: Olympic track or an accurately measured site that has neither slopes nor significant modifications. Stopwatch.

Protocol: consists of running continuously for 12 minutes, and attempting to cover the greatest distance possible in that time. Individuals cannot stop, but they can walk if they need to. The distance is recorded once the time is up. This test can be carried out by both men and women over 13 years of age. The test allows various subjects to be tested simultaneously without complicated tools and with few people to monitor it. Different studies on the reliability of the test give it a value that ranges from r=.24 and 0.94 (Carzola, 1990) with respect to the VO_2max.

VO_2max calculations. (ml/kg/min):

a- **VO_2max. (ml/kg/min) = (Distance in meters. – 504)/45**

b- **VO_2max. (ml/kg/min) =22,351 x distance in km. – 11,288**

The following Tables 1, 2, and 3 allow Cooper test results to be ranked using the VO_2max estimation or according to the distance run.

Table 1: Cooper test values (Howley and Franks, 2000)

Good		
15-34	>2,400 m (7,874 ft)	>2,800 m (9,186 ft)
35-54	>2,200 m (7,217 ft)	>2,500 m (8,202 ft)
55-70	>1,900 m (6,233 ft)	>2,100 m (6,889 ft)
Average		
15-34	2,200 m (7,217 ft)	2,400 m (7,874 ft)
35-54	2,100 m (6,889 ft)	2,200 m (7,217 ft)
55-70	1,800 m (5,905 ft)	2,100 m (6,889 ft)
Below Average		
15-34	2,100 m (6,889 ft)	2,200 m (7,217 ft)
35-54	1,900 m (6,233 ft)	2,100 m (6,889 ft)
55-70	1,600 m (5,249 ft)	1,900 m (6,233 ft)
Poor		
15-34	<1,900 m (6,233 ft)	<2,100 m (6,889 ft)
35-54	<1,700 m (5,577 ft)	<1,900 m (6,233 ft)
55-70	<1,400 m (4,593 ft)	<1,600 m (5,249 ft)

Source: Howley and Franks, 2000.

Table2: Classification according to meters run in 12 minutes by men (García Manso, Navarro Valdivielso, and Ruiz Caballero, 1996)

AGE	**13 - 19**	**20 - 29**	**30 – 39**	**40 – 49**	**50 - 59**	**>60**
Distance	**m**	**m**	**m**	**m**	**m**	**m**
Poor	2100 (6,889 ft)	1950 (6,397 ft)	1900 (6,233 ft)	1850 (6,069 ft)	1650 (5,413 ft)	1400 (4,593 ft)
Below average	2200 (7,217 ft)	2100 (6,889 ft)	2100 (6,889 ft)	2000 (6,561 ft)	1850 (6,069 ft)	1650 (5,413 ft)
Average	2500 (8,202 ft)	2400 (7,874 ft)	2350 (7,709 ft)	2250 (7,381 ft)	2100 (6,889 ft)	1950 (6,397 ft)
Good	2750 (9,022 ft)	2650 (8,694 ft)	2500 (8,202 ft)	2500 (8,202 ft)	2300 (7,545 ft)	2150 (7,053 ft)
Very good	3000 (9,842 ft)	2850 (9,350 ft)	2700 (8,850 ft)	2650 (8,694 ft)	2550 (8,366 ft)	2500 (8,202 ft)
Excellent	3000 (9,842 ft)	2850 (9,350 ft)	2750 (9,022 ft)	2650 (8,694 ft)	2550 (8,366 ft)	2500 (8,202 ft)

Source: García Manso, Navarro Valdivielso, M. Ruiz Caballero, 1996.

Table3: Classification according to meters run in 12 minutes by women (García Manso, Navarro Valdivielso, and Ruiz Caballero, 1996)

AGE	**13 – 19**	**20 - 29**	**30 – 39**	**40 - 49**	**50 - 59**	**>60**
Distance	**m**	**m**	**m**	**m**	**m**	**m**
Poor	1600 (5,249 ft)	1550 (5,085 ft)	1500 (4,921 ft)	1400 (4,593 ft)	1350 (4,429 ft)	1250 (4,101 ft)
Below average	1900 (6,233 ft)	1800 (5,905 ft)	1700 (5,577 ft)	1600 (5,249 ft)	1500 (4,921 ft)	1400 (4,593 ft)
Average	2100 (6,889 ft)	1950 (6,397 ft)	1900 (6,233 ft)	1800 (5,905 ft)	1700 (5,577 ft)	1600 (5,249 ft)
Good	2300 (7,545 ft)	2150 (7,053 ft)	2100 (6,889 ft)	2000 (6,561 ft)	1900 (6,233 ft)	1750 (5,741 ft)
Very good	2450 (8,038 ft)	2350 (7,079 ft)	2250 (7,381 ft)	2150 (7,053 ft)	2100 (6,889 ft)	1900 (6,233 ft)
Excellent	2600 (8,530 ft)	2450 (8,038 ft)	2350 (7,709 ft)	2150 (7,053 ft)	2100 (6,889 ft)	1900 (6,233 ft)

Source: García Manso, Navarro Valdivielso, M. Ruiz Caballero, 1996.

Klissouras test or 1,000 meter test (Klissouras)

This test is generally used to estimate the VO_2 in children of less than 13-14 years-old. This does not mean it cannot be adapted for adults. We recommend using this test for average performance athletes in order to check their VO_2max or maximal aerobic speed (MAS).

Material: Olympic track or an accurately measured site that has neither slopes nor significant modifications. Stopwatch.

Protocol: the test consists of running 1,000m (3,280 ft) and attempting to complete the distance in the shortest time possible. The runner cannot stop. The time is recorded upon completing the distance.

VO_2max calculations. (ml/kg/min):

$VO_2max = (652.17 – \text{Time for 1000 m in sec.}) / 6.76$

Cureton Test or the 1-mile test (Cureton, 1990)

Material: running track or an accurately measured site that has neither inclinations nor significant modifications. Stopwatch.

Protocol: this test consists of running 1609 m (5278 ft) and recording the time it takes to complete it. Individuals must aim to complete the required distance in the fastest possible time, which then becomes a max test.

Important: the subject's sex, bodyweight, height and age should also be known.

VO_2max calculations. (ml/kg/min):

VO_2max = - 8.41 x (min. Time) + 0.34 x (min Time)2 + 0.21 x (Age x Gender) – 0.84 x (BMI) + 108.94

Where:

- Time: the time is recorded in decimal minutes and seconds. In order to obtain the decimal time corresponding to the seconds, divide the seconds by 6 and add it to the whole number that is represented by the minutes.
- Age: years and months (millesimal age).
- Gender: sex. Male: 1. Female: 0.
- BMI: Body Mass Index ($Weight/height^2$).

ACSM Treadmill test

Material: treadmill, stopwatch, spreadsheet for recording data and cardiotachometer.

Description: this tests estimates VO_2max and is an indirect, maximal test. It can be used for professional as well as recreational athletes as long as they are cleared by a medical doctor.

The test consists of the following protocol:

- The subject begins the test at a speed of 4 mph (6.4 km/h) and this is increased each minute.
- The increase is 0.5 mph (0.8 km/h) for beginners and 1 mph (1.6 km/h) for athletes.
- The test ends when the subject can no longer maintain the speed.

Results: the test provides the final speed in mph or km/h of the last minute completed. This data should be converted to meters/min in order to estimate VO_2max.

VO_2max calculations. (ml/kg/min):

VO_2max. (ml/kg/min) = V * 0.20 + 3.5

Where V = final speed in meters/minute (ASCM, 2000).

Important: It is vitally important that the subject has experience in running at top speed on a treadmill, in order to avoid accidents and to ensure that the test truly measures an athlete's maximum capacity. It has an r = 0.91 (Jiménez Gutiérrez, 2005).

5 minute test (Berthoin, Fellmann, Bedu, Beaune, Dabonneville, Coudert, & Chamoux, 1997)

The general characteristics of this test are the following:

- Continuous, steady maximal (cyclic) test.
- Running for 5 minutes and attempting to cover the greatest distance possible.
- Appropriate surface (footwear and site).

The test consists of the following protocol:

- It begins with a 5/10 min warm up at 70% HRmax (which allows the subject to start the test at full strength.
- A constant rhythm is needed to obtain maximum performance for 5 minutes.
- Subjects cannot rest during the test.
- The shuttle technique was excluded since it introduces additional factors (muscle strength, change of direction technique, reactivity) which can modify performance.

The main objective of this test is to estimate the maximal aerobic speed (MAS) or vVO_2max.

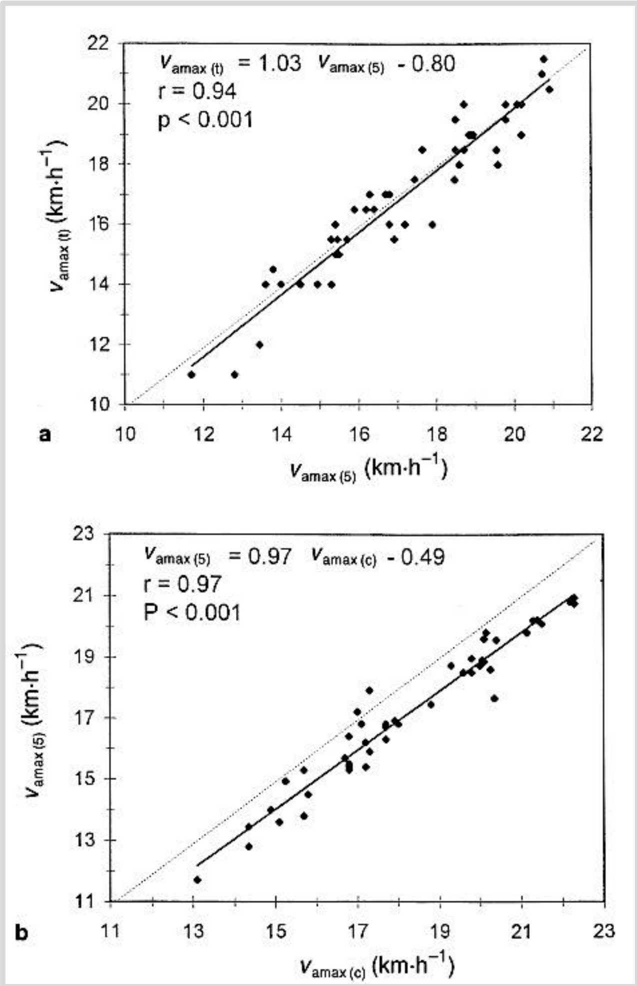
The maximal aerobic speed [vVO_2max (in km/h)] is calculated by multiplying the distance covered during the test (d) by 12 (1 h = 5 min * 12): vVO_2(km to h ± 1) = 12 d (km run in 5 min).

MAS (km/h) = 12 x distance in km run during the test.

The Leger-Mercier equation (1983) developed for the test by the University of Montreal (1983) was used in this case to estimate VO_2max (Figures 1 and 2).

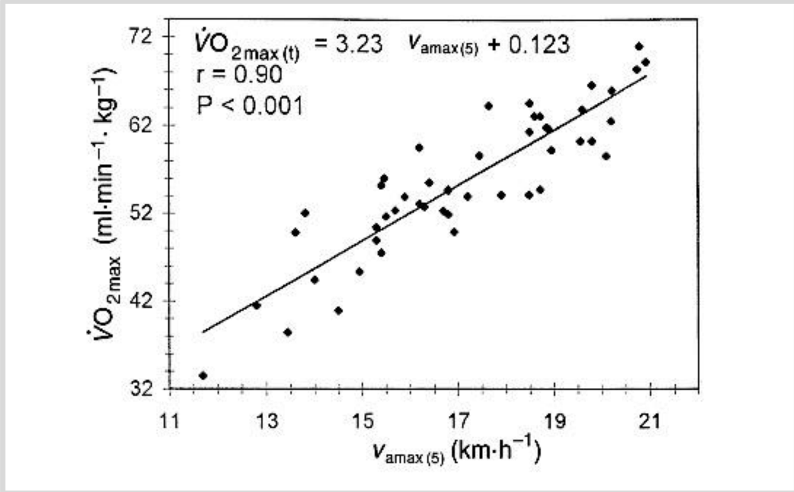
VO_2max (ml/kg/min)= 3.23 x MAS + 0.123

Figure 1: The relationship between maximal aerobic speed (MAS), measured on the treadmill at vVO_2max (t) and at running speed maintained during the 5 minute MAS test (5), and between MAS (5) and the last stage completed in the University of Montreal's (UMTT) MAS test (c)



Source: Berthoin, Fellmann, Bedu, Beaune, Dabonneville, Coudert, & Chamoux, 1997.

Figure 2: Relationship between VO_2max measured on a treadmill and MAS (5) measured by the 5 minute test



Source: Berthoin, Fellmann, Bedu, Beaune, Dabonneville, Coudert, & Chamoux, 1997.

University of Montreal Test (UMTT) (Leger & Boucher, 1980)

The main goal of this test is to estimate the VO_2max according to an estimated maximal aerobic speed (MAS or vVO_2max). This is a continuous incremental maximal test targeted at athletes.

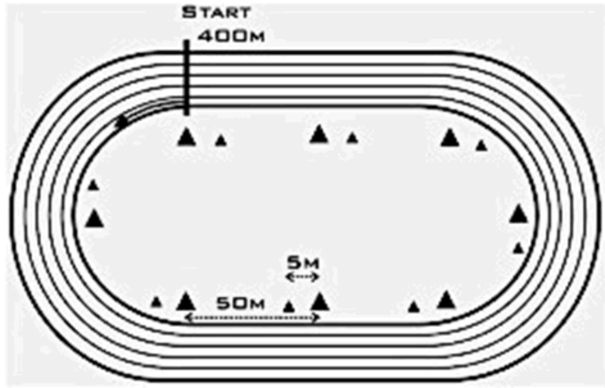
Materials: Running track, cones, CD with the test audio, audio player that can be heard throughout the running track, data collection spreadsheet and cardiotachometer to measure heart rate (HR) (optional).

The test consists of the following protocol:

- Cones are placed every 25 m (82 ft) on a running track (400 m [1312 ft] or 200 m [656 ft]). The subjects being evaluated stand behind the start line and on the signal from the audio they begin running at a speed of 6 km/h (3.7 mph). At each audio signal, the runner should be passing a cone.
- Every 2 minutes the speed is increased by 0.5 km/h (0.3 mph).
- When the subject cannot maintain the speed (is not arriving at the cone when the signal sounds), the test has finished.

Table 4: Protocol for the University of Montreal track test (UMTT) (Leger and Boucher, 1980)

Step	VO_2 [$ml \cdot kg^{-1} \cdot min^{-1}$]	Time (min)	Speed (km/h)	Time every 50 m (s)
Walk				
5	17,5	2	6,00	30,0
7	24,5	4	7,10	25,4
Run				
9	31,5	6	7,16	25,1
10	35,0	8	8,48	21,2
11	38,5	10	9,76	18,4
12	42,0	12	11,00	16,4
13	45,5	14	12,21	14,7
14	49,0	16	13,39	13,4
15	52,5	18	14,54	12,4
16	56,0	20	15,66	11,5
17	59,5	22	16,75	10,7
18	63,0	24	17,83	10,1
19	66,5	26	18,88	9,5
20	70,0	28	19,91	9,0
21	73,5	30	20,91	8,6
22	77,0	32	21,91	8,2
23	80,5	34	22,88	7,9



Source: Adapted by Leger and Boucher, 1980.

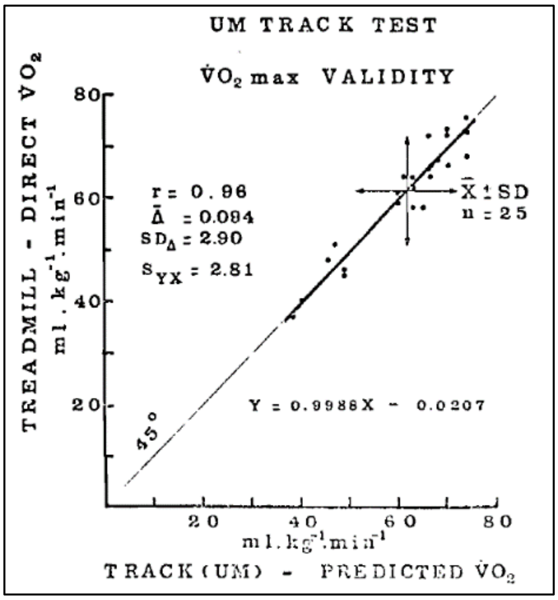
Results: The MAS (vVO_2max) is recorded, which is the maximal speed reached during the last completed stage. If a cardiotachometer was used, then it records the final HR.

VO_2max (ml/kg/min) = 3.5 * V

Where V: Speed in km/h of the last completed stage.

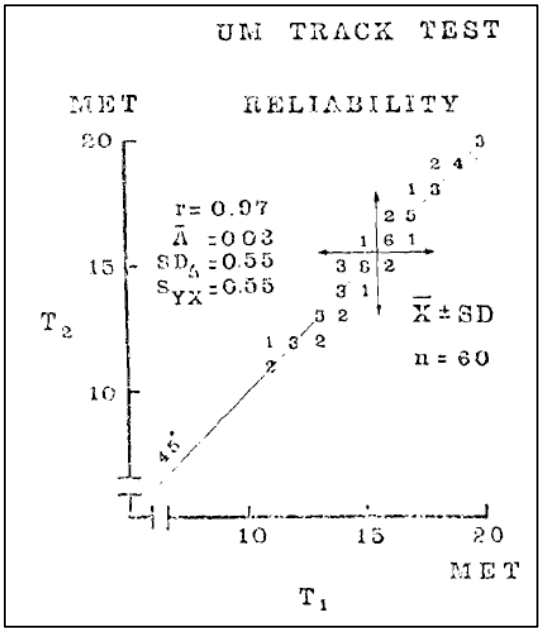
The reliability correlation coefficient is r=0.96 (Leger and Boucher, 1980).

Figure 3: Reliability of the UMTT test for estimating VO_2max. (r=0.96)



Source: Leger and Boucher, 1980

Figure 4: Reliability of the UMTT test (r=0.97)



Source: Leger and Boucher, 1980

Another equation which can be used to estimate the VO_2max using the UMTT data is the following:

VO_2max (ml/kg/min)= 1.353 + (3.163 * V) + (0.0122586 * V2)

Where V: speed in km/h of the last completed stage.

For this second equation, the reliability correlation coefficient is r = 0.97.

Another aspect that should be considered is that although it is well-known that the speed reached in the last stage of the test is associated with the VO_2max, in order for this information to be reliable and useful for training plans, it must be corroborated by a time limit test (Tlim100%vVO_2 max).

Some comments on the UMTT

The University of Montreal test (UMTT) is both a valid and reliable test for estimating VO_2max (Lacour et al., 1991). The speed reached during the UMTT (vUMTT) provides a precise estimation of vVO_2max which is similar to the measurements taken on a treadmill in the lab (Leger and Boucher, 1980).

The higher level of accuracy in determining the VO_2max is probably helped by the recording which gradually increases the speed and eliminates the variation caused by autostimulation. However, despite the high accuracy, it has also been reported that the vVO_2max measured in a lab is probably slightly lower (1.2% - 0.07 m/s) than the vUMTT (Billat & Koralsztein, 1996; Lancour, Padilla-Magunacelaya, Chatard, Arsac, & Barthelemy, 1991). It is quite possible that the test protocol itself could cause this discrepancy, since each stage of the UMTT lasts 2 minutes, whereas the vVO_2max protocols carried out on a treadmill can last up to 4 minutes and can include an incline (Eston & Reilly, 2009).

The UMTT protocol might also allow for a slight increase in the contribution made by the anaerobic energy system caused by the end of the test, since the MRS (Maximum running speed) is calculated when the athlete has reached complete exhaustion once the test has finished (Leger & Boucher, 1980). This test has been used previously in sports such as soccer, although it could be more applicable to strength sports which use more lineal and continuous movements. (Clarke et al., 2016).

MAS-EVAL Test (Cazorla and Leger, 1993)

The main goal of this test is to estimate VO_2max and the maximal aerobic speed (MAS or vVO_2max). This is a continuous incremental maximal test targeted at athletes.

Materials: Running track, cones, CD with the test audio, audio player that can be heard throughout the running track, data collection spreadsheet and cardiotachometer to measure heart rate (HR) (optional).

The test consists of the following protocol:

- Cones are placed every 25 m (82 ft) on a running track (400 m [1312 ft] or 200 m [656 ft]). The subjects being evaluated stand behind the start line and on the signal from the audio they begin running at a speed of 6 km/h. At each audio signal, the runner should be passing a cone.

- Every 1 minute the speed is increased by 0.5 km/h (0.3 mph). When the athlete cannot maintain the speed (is not arriving at the cone when the signal sounds), the test has finished.

Results: The MAS (vVO_2max) is recorded, which is the maximum velocity reached during the last completed stage. If a cardiotachometer is used, then it records the final HR.

VO_2max (ml/kg/min) = 3.5 * V

Where V: speed in km/h of the last completed stage.

The reliability correlation coefficient is r=0.96 (Leger and Boucher, 1980).

As in the UMTT, another aspect that should be considered is that although it is well-known that the speed reached in the last stage of the test is associated with the VO_2max, in order for this information to be reliable and useful for training plans, it must be corroborated by a time limit test ($Tlim100\%vVO_2max$).

3.2.2 General Endurance Test II

Maximal, indirect acyclic field tests

Multistage-Fitness Test. Shuttle test. 20-M Shuttle Run Test (Leger y Lambert, 1982; Leger, Mercier, Gadoury & Lambert, 1988)

The 20 m (65 ft) shuttle test, commonly known as the 20-M Shuttle Run Test (20SRT) (Leger and speed and with a protocol of running back and forth (shuttle) designed to predict the VO_2max (Leger and Lamber, 1982). This test has been used in sports such as squash (St. Clair Gibson, Broomhead, Lambert, & Hawley, 1998) and soccer (Aziz, Yau & Chuan, 2005), as well as with active children and adults (Leger et al., 1998, Ramsbottom, Brewer & Williams, 1988).

Objective: to estimate/predict VO_2max.

The original protocol used 2 minute stages (Leger & Lambert, 1982), but was later adapted to use 1 minute stages due to the time required to register the vVO2max (Leger et al., 1988). This protocol has been revalidated in successive studies for predicting the VO_2max in children and adults (Leger & Lambert, 1982, Ramsbottom et al., 1988) and has been consistently reliable in multiple trials (Aziz, Yau and Chuan, 2005).

Material: A flat site with 20 meters (65 ft) marked off. Audio equipment with a CD of the specific test signals. Stopwatch.

Description: This test involves the subjects running a distance of 20 m (65 ft) back and forth (shuttle), in other words, every 20 meters (65 ft) they have to intersperse accelerations with braking. The test consists of running 20 meters (65 ft) at a speed which increases with each stage or section of 1 minute, as indicated by the auditory signals (beep). The beeps become faster every minute and so the subject also has to increase his or her speed.

VO_2max is estimated through the running speed that is reached during the final stage or stretch that the subject was able to maintain. This test is very useful for determining the aerobic abilities of subjects with low, medium and high physical conditioning, but is less useful for older subjects and those with a very low level of physical conditioning.

Subjects begin the test running at a speed of 8km/h (4.9 mph) for the first minute, and from then onwards the speed is increased every minute by 0.5 km/h (0.3 mph). The speed recorded comes from the last stage completed before stopping and is inserted in the VO_2max prediction equation. This test is maximal, continuous, acyclic and progressive.

VO_2max calculations. (ml/kg/min).

For individuals older than 19 years of age (both sexes)

VO_2max = 5.857 x Velocity (km/h) – 19.458

For individuals from 6 to 18 years of age (both sexes)

VO_2max = 31.025 + (3.238 x V) – (3.248 x A) + (0.1536 x V x A)

Where:

V: Maximal Velocity in Km/h.
A: Age in years.

Table 5 is used to determine the VO_2max (ml/kg/min) based on the velocity of the last stage completed (km/h) and using the above equations. This test has an r = 0.84 (Jiménez, 2005).

Table 5: Multi-Stage Fitness Test Table / Shuttle test / 20-M Shuttle Run Test

Endurance test (Multi-stage fitness test)			
Stages (minutes)	Speed in km/h	Split time (seconds)	Distances traveled (m)
1	8	9.00	133
2	9	8.00	283
3	9.5	7.58	441
4	10	7.20	608
5	10.5	6.86	783
6	11	6.54	966
7	11.5	6.26	1158
8	12	6.00	1358
9	12.5	5.76	1566
10	13	5.54	1783
11	13.5	5.33	2008
12	14	5.14	2241
13	14.5	4.97	2483
14	15	4.80	2733
15	15.5	4.64	2991
16	16	4.50	3258
17	16.5	4.36	3533
18	17	4.23	3816
19	17.5	4.11	4108
20	18	4.00	4408
21/23	18.5	3.90	

Source: [Untitled image on Multi-Stage Fitness Test table]. (Undated). Recover from http://goo.gl/mjvsH8

To estimate the VO_2max, the velocity of the last completed stage is used.

Some notes on the Multi-Stage Fitness Test / shuttle test / 20-M Shuttle Run Test (SRT)

During the 20SRT, the MRS is taken from the last completed stage (v20SRT), despite the fact that there could be a variation between individuals who finish at the same time, and that each stage consists of multiple round trips (which means taking into consideration the development of the neuromuscular system, the capacity to accelerate and decelerate and the ability to change direction, among other aspects). Nonetheless, it has been reported that the reliability of the test does not change when the final velocity of the test is considered instead of the distance covered (O'Gorman, Hunter, McDonnacha, & Kirwan, 2000).

The 20SRT sometimes underestimates the VO_2max of the evaluated subjects (Berthoin et al., 1997), particularly if they are trained athletes. This could be because the effort required to run back and forth makes it harder to maintain a rhythm of high speed running, which in turn makes complete aerobic energy contribution more difficult. The back and forth speeds are slower than those run in a straight line due to the time needed for deceleration and acceleration (Ahmaidi, Collomp, Caillaud, & Pre'faut, 1992; Leger & Lambert, 1982). Due to the difference between lineal and shuttle evaluations, the v20SRT should be converted so that it can be used as a kind of lineal training style after applying a linear regression equation (Berthoin et al., 1997). As this conversion would still be an estimation, the 20SRT protocol cannot be adapted for athletes with a high level of physical conditioning, and it can therefore be concluded that this test is not suitable for individualized sessions, whichever the sport (Clarke, 2016).

Yo-Yo Endurance Test (Bangsbo, 1996; 1997)

Bangsbo (1996, 1997) developed a new version of the Multi-Stage Fitness Test (Leger and Lambert, 1982, Leger et al., 1988). The implementation is similar to that of its predecessor, as is the conversion table and the final results measured either in meters or in the number of return trips completed. The starting velocity is 8 km/h (4.9 mph) and is increased by 0.5 km/h (0.3 mph) every minute.

Objective: to estimate/predict VO_2max.

Material: A flat site with 20 meters (65 ft) marked off. Audio equipment with a CD of the specific test signals. Chronometer.

The special feature of this test is that it has two versions, one for beginners and one for advanced athletes. The first version (level 1) begins at 8 km/h (4.9 mph) while the second version (level 2) begins at 11.5 km/h (7.1 mph). To advance from one level to the next, an athlete must have reached cone speed 17 at level 1, (a minimum VO_2max level of 68 ml/kg/min).

Bangsbo provides a table that correlates the velocity reached (level1) with VO_2max (Table 6).

Table 6: *Yo-Yo Endurance Test Table Level 1* (allows VO_2max to be estimated according to the stage reached during the test)

Results	**VO_2max.**	**Results**	**VO_2max.**
Velocity Level Reached	*Ml/kg/min.*	*Velocity Level Reached*	*Ml/kg/min.*
5.2	27.1	11.4	48.0
5.4	28.0	11.4	49.2
5.6	28.5	11.8	49.9
5.9	29.9	11.11	50.9
6.2	30.5	12.2	51.4
6.4	31.4	12.4	52.0
6.6	32.2	12.6	52.6
6.9	33.2	12.8	53.1
7.2	34.0	12.10	53.7
7.4	34.6	12.12	54.2
7.6	35.6	13.2	54.9
7.8	36.1	13.4	55.5
7.10	36.7	13.6	56.0
8.2	37.5	13.8	56.6
8.4	38.3	13.10	57.1
8.6	39.1	13.12	57.7
8.8	39.7	14.2	58.1

8.10	40.6	14.4	58.7
9.2	41.1	14.6	59.2
9.4	41.6	14.8	59.8
9.6	42.4	14.10	50.4
9.8	43.0	14.13	61.2
9.11	43.9	15.2	61.7
10.2	44.4	15.4	62.2
10.4	45.0	15.6	62.8
10.6	45.7	15.8	63.3
10.8	46.3	15.10	63.9
10.11	47.4	15.13	64.7
11.2	47.9	16.2	65.2

Source: Bangsbo, 1996.

Bangsbo provides a table that correlates the velocity level reached during the test (level 2) and the VO_2max (Table 7).

Table 7: *Yo-Yo Endurance Test Table Level 2* (allows VO_2max to be estimated according to the stage reached during the test)

Results	**VO_2max.**	**Results**	**VO_2max.**
Velocity Level Reached	*Ml/kg/min.*	*Velocity Level Reached*	*Ml/kg/min.*
16.4	65.8	19.6	77.6
16.6	66.3	19.8	78.1
16.8	66.9	19.10	78.6
16.10	67.4	19.12	79.2
16.13	68.2	19.15	80.0
17.2	68.7	20.2	80.5
17.4	69.2	20.4	81.1
17.6	69.8	20.6	81.6
17.8	70.3	20.8	82.1
17.10	70.9	20.10	82.7
17.12	71.4	20.12	83.2
17.14	72.0	20.15	83.8
18.2	72.6	21.2	84.5
18.4	73.1	21.4	85.1
18.6	73.6	21.6	85.6
18.8	74.2	21.8	86.1
18.10	74.8	21.10	86.7

18.12	75.3	21.12	87.2
18.14	75.9	21.14	87.8
19.2	76.4	21.16	88.3
19.4	77.0		

Source: Bangsbo, 1996.

Finally, two tables are presented (Tables 8 and 9) with VO_2max data for subjects with recreational fitness levels and subjects with high performance fitness levels in order to compare results if necessary.

Table 8 VO_2max data in recreational population (Howley and Franks, 2000)

Age in years	VO_2max. (ml/kg/min). Women	VO_2max. (ml/kg/min). Men
Good		
15-34	>40	>45
35-54	>35	>40
55-70	>30	>35
Average		
15-34	35	40
35-54	30	35
55-70	25	30
Below Average		
15-34	30	35
35-54	25	30
55-70	20	25
Poor		
15-34	<25	<30
35-54	<20	<25
55-70	<15	<20

Source: Howley and Franks, 2000.

Table 9: Typical values of VO_2max in various sports (ml/kg/min) (Howley and Franks, 2000)

Sport	VO_2max (ml/kg/min). Men	VO_2max (ml/kg/min). Women
Strength		
Base (A)	75-80	65-70
Skiing	75-80	65-70
Biathlon	75-80	65-70
Road cycling	70-75	60-65
Middle distance running	70-75	65-68
Skating	65-72	60-65

Long Distance running (N)	60-70	55-60
Rowing	65-69	60-64
Canoeing	60-68	50-55
Walking	60-65	55-60
Acyclic sports		
Soccer	60-65	45-48
Handball	55-60	48-52
Ice hockey	55-60	-
Volleyball	55-60	48-52
Tennis	48-52	40-45
Table tennis	40-45	38-42
Combat Sports		
Boxing	60-65	-
Wrestling	60-65	-
Judo	55-60	50-55
Fencing	45-50	40-45
Track and field strength sports		
Running 200 m	55-60	45-50
Running 100 m	48-52	43-47
Long jump	50-55	45-50
Decathlon	60-65	50-55
Weightlifting	40-50	-
Discus	40-45	35-40
Javelin	45-50	42-47
Pole Vaulting	45-50	-
Ski Jumping	40-45	-
Technical acrobatic sports		
Alpine skiing	60-65	48-53
Figure skating	50-55	45-50
Gymnastics	45-50	40-45
Rhythmic gymnastics	-	40-45
Sailing	50-55	45-50
Shooting	40-45	35-40

Source: Howley and Franks, 2000.

Assessment of intermittent endurance

The Yo-Yo intermittent recovery test and the Yo-Yo intermittent endurance test evaluate the ability to repeatedly perform intervals over a prolonged period of time, and to recover during progressively increasing effort, respectively.

Yo-Yo Intermittent Endurance Test (YYIE) (Bangsbo, 1996; 1997)

Main objective: to use intermittent exercise to progressively induce a maximal response from subjects. Related to this main objective is the assessment of an athlete's ability to withstand efforts of growing intensity during intermittent endurance exercises.

Description: Following the description by Vargas (2008), the test consists of periods of running interrupted by brief phases of recovery. The test requires 20 meters (65 ft) of running space, with a line at each end and a third line 2.5 meters (8 ft) behind the starting line.

On the initial beep, the subject runs towards the 20 meter line and should arrive at the exact moment the second beep sounds. The subject then changes direction and returns to the starting line, where the third beep will sound. Once back at the starting line, the subject continues running/jogging at a slower speed and has 5 seconds to turn and get back to the starting line, where the fourth beep will sound. This sequence is repeated until the subject fails twice (although not necessarily consecutively) to keep up the speed, which increases progressively. The first time a player fails to make it back to the start line in the allocated time set by the beep the player receives a warning message, and the second time he fails, the subject must stop. The test is completed at this point. The goal of the test is to complete as many shuttles (out and back) as possible. The duration of the test can vary from 5 to 30 minutes, depending on the subject's level.

Once finished, the number of shuttles, the number of fractions of 2 by 20 meters (65 ft) run in the last step (even if they were not completely finished) and the final velocity are recorded.

When there are subjects with different levels, the lower level subject starts at a speed of 8 km/h (4.9 mph) (step 1), while the higher level starts at a speed of 11 km/h (6.8 mph) (step 8). A subject advances from level 1 to level 2 when they are able to complete level 1 successfully. It should be made clear that these tests do not estimate maximal oxygen consumption (VO_2max), nor a subject's maximal aerobic speed (MAS) since the correlation is very low (r) (Ruspantini, 2005).

Table 10 shows reference data for the Yo-Yo intermittent endurance test.

Table 10: Reference data for the Yo-Yo intermittent endurance test (Ruspantini, 2005)

Athletes	**Level 1**	**Authors**
18 16-year-old soccer players	2,914 m (± 448 m) [9,560 ft (± 1,469 ft)] 11.5:1 13.25 km/h	(Castagna and Belardinelli, 2006)
Athletes	**Level 2**	**Authors**
Elite runners	2,960 m (2,680 – 3,560 m) [9,711 ft (8,792 – 11,679 ft)] 18.5:22 (18:1 – 19.5:5) 16.75 km/h (16.5 – 17.25)	(Bangsbo, 1997)
Elite soccer players	2,280 m (1,960 – 3,200) [7,480 ft (6,430 – 10,498)]	(Bangsbo, 1997)

	17:3 (16.5:1 – 19:2) 16 km/h (15.75 – 17 km/h)	
114 players from Portugal's elite divisions A and B	1,158 m (± 263.1 m) [3,799 m (± 863.2 ft)] 14:7 14.5 km/h	(Oliveira et al., 1998)
17 basketball players	1,287.06 m (± 395.53 m) [4,222.63 ft (± 1,297.67 ft)] 14.5:2 14.75 km/h	(Calafate and Janeira, 1998)

Source: Ruspantini, 2005.

Yo-Yo Intermittent Recovery Test (YYIRT) (Bangsbo, 1996; 1997)

This test evaluates an individual's ability to perform intense exercise (Bangsbo, Laia, & Kustrup, 2008). It includes high intensity accelerations, decelerations and changes of direction (COD). It also includes incomplete recovery in high intensity exercise.

Main objective: to use intermittent exercise with pauses to progressively induce a maximal response from subjects. It also assesses an athlete's ability to recover during high intensity intermittent endurance exercises with short pauses between efforts.

Description: The test consists of running back and forth between two lines, placed 20 meters (65 ft) apart, and on finishing stages of 40 meters (141 ft) (1 shuttle), the subject has 10 seconds of active recovery time (at a slow jog) turning behind the starting point towards a third line placed 5 meters (16 ft) from the starting point at an angle of 30 degrees.

Running speed and the 10 second recovery time are marked throughout the test by a beep.

The starting speed is 10 km/h (6 mph) (step 5) for level 1 and 13 km/h (8 mph) (step 11) for level 2. In order to pass from one level to the next, the subject must be able to reach step 15 of level 1 (Bangsbo, 1997). The first time the subject is not able to reach the line as the beep sounds, a warning is given, and the second time the subject must stop, effectively ending the test. The length of the test may vary from 5 to 15 minutes, depending on the subject's level.

Both levels of this test focus on the recovery ability during intense intermittent exercise with high aerobic (level 1) and anaerobic (level 2) contributions.

The results of the test can be seen in the number of steps achieved, the number of shuttles, the number of total meters run and the final velocity.

This test is especially important for evaluating athletes in sports which are dominated by alternating phases of high intensity activity (16 to 25 km/h, 10 to 15 mph) and medium or low intensity activity (running, jogging, walking or standing still), such as football, basketball, volleyball, tennis, handball, rugby, etcetera. Good inter-effort recovery abilities will definitely support the subject's technical performance.

In a study carried out on 44 Danish professional soccer players (Reilly, Bangsbo and Franks, 2002), midfielders proved to have the best recovery abilities compared to players in different positions on the same team. This study confirms and shows that midfielders have the highest VO_2max values, and that this value is very significant for soccer players during the recovery phase (Bangsbo, 1997).

It should be noted that the YYIRT must not be used to estimate VO_2max or the maximal aerobic speed (MAS) of athletes. The estimation of VO_2max is inaccurate due to the contribution of the anaerobic energy systems, the development of the ability to change direction (COD) and the inter-effort recovery capacity during the test (Bangsbo et al., 2008).

An MRS for these tests is established using the velocity reached in the last stage (Castanga, Impellizzeri, Charmari, Carlomagno, & Rampini, 2006) or a previously developed equation (Kuipers et al., 1985), together with the YYIRT (Dupont et al. 2010). Using the final stage velocity could generate the same problems discussed in the 20SRT, whereby athletes reach the same stage but complete a different number of shuttles. In contrast, it is felt that the above-mentioned equation could provide an almost perfect relationship between the distance covered and the MRS as shuttles completed (Kuipers et al., 1985).

Although the use of tests based on the number of completed shuttles for determining an MRS could be questionable, this test is commonly used in intermittent dynamic sports (like soccer) because of its greater sensitivity in identifying changes in performance compared to VO_2max. (Krustrup & Bangsbo, 2001). Table 11 shows some reference values.

Table 11: Reference values for the Yo-Yo intermittent recovery test level II

Athletes	Results	Author
Elite runners	1,240 m (960 – 1,520 m) [4,068 ft (3,149 – 4,986 ft)] 22:4 (21:5-23:3) 18.5 km/h	(Bangsbo, 1997)
Elite soccer players	1,000 m (600 - 1320 m) [3,280 ft (1,968 - 4,330 ft)] 21:6 (20:4 - 22:6) 18 km/h (11 mph)	(Bangsbo, 1997)

Source: Bangsbo, 1997.

30-15 Intermittent Fitness Test (30-15 IFT) (Buchheit, 2008)

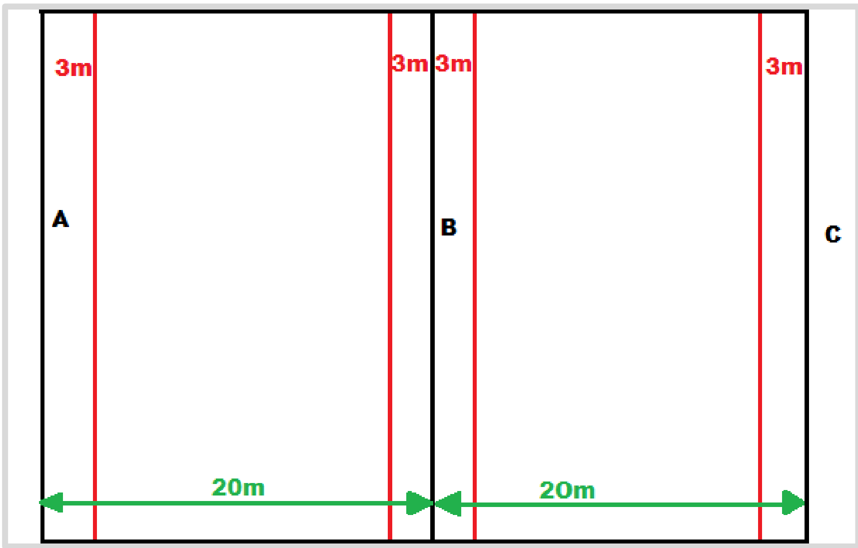
The main objective of this test is to provide a reference speed in order to program high intensity interval (intermittent) training sessions that include changes of direction (Buchheti, 2008) (Del Rosso, 2013a).

The general characteristics of this test are the following:

- Shuttle test.
- It includes accelerations, decelerations and changes of direction (COD).
- Alternating 30 seconds of effort with 15 seconds of rest.
- Accelerations have an important metabolic component.
- Decelerations and COD involve an important neuromuscular (mechanic) component.

Protocol: the 30-15 IFT consists of 30-second shuttle runs, interspersed by 15-second recovery periods. The starting velocity is 8km/h (4.9 mph) and it is increased by 0.5 km/h (0.3 mph) in each subsequent 30-second stage (well trained athletes can begin the test at 10 or even 12 km/h [6 or even 7.5 mph]). Athletes must run back and forth between two lines that are 40 m (131 ft) apart (Figure 5) at a speed determined by an auditory signal. The prerecorded signal lets individuals adjust their running speed as they enter the 3 meter zone located in the middle and on each end of the test site. During the 15 second passive recovery period, players walk forwards towards the closest line; this could be the middle line or the lines at the two ends, depending on where they finished the last stage. This line is now the starting point of the next stage. Subjects must be told that they are attempting to complete the highest number of stages possible. The test ends when the athletes cannot maintain the required running speed or when they fail to reach the 3 meter zone together with the auditory signal three consecutive times. The velocity of the last completed stage determines the velocity of the player's Intermittent Fitness Test (VIFT) (Buchheit, 2008).

Figure 5: Illustration showing the space required for the 30-15 IFT. The 3 meter zones can be seen



Source: Buchheit, 2008.

VO_2max can be estimated from the VIFT by using the following equation:

VO_2max 30-15 IFT (ml/kg/min) = 28.3 - 2.15 G - 0.741 A -0.0357 W + 0.0586 A x VIFT + 1.03 VIFT

Where G is the sex (Women = 2, Men = 1); A is the age and W is the weight in kg.

Important considerations for the 30-15 IFT

The final velocity of the 30-15 IFT (vIFT) is significantly correlated with the VO_2max (r=0.68), the countermovement jump height (CMJ) (r=0.65) and the 10 meter acceleration velocity (r=0.63) (Buchheit, 2008).

Due to the effect of the ability to change direction on shuttle speed, 0.7 seconds is taken off for each change of direction (Buchheit, 2008). For example, at a linear velocity of 11.5 km/h (7 mph) an athlete can cover 96 meters (314 ft) in 30 seconds, while in a 40 meter (131 ft) shuttle run, two changes of direction are required (2 x 0.7 seconds), so the distance covered at that speed is reduced to 91.6 meters (300 ft) (11.5km/h [7 ft] in 28.6 seconds) (Buchheit, 2008).
This conversion helps the 30-15 IFT to provide valid and reliable performance measurements in multi-directional accelerations (Buchheit, 2008). The vIFT also allows athletes with different physiological profiles to achieve the same level of cardiorespiratory demand during training (Buchheit, 2008), thus making it an excellent test for the individualization of multidirectional, supramaximal conditioning in intermittent sports such as soccer, basketball and rugby (Buchheit, 2008).

3.2.3 Considerations on Maximal Field Tests (Cyclic and Acyclic) for Determining Training Speed

The prescription of generalized training, where the athletes' training is either all low or all high intensity, could either cause a lack of adaptation or overtraining, respectively (Kuipers et al., 1988). It has been reported that the use of training velocity can be accurate and highly effective during the development of aerobic and anaerobic fitness (Blondel, Berthoin, Billat, & Lensel, 2001, Buchheit, 2008). Despite all the information available on the use of highly variable speed training (Baquet, Berthoin, Gerbeaux, & Van Praagh 2001; Berthoin, Manteca, Gerbeaux, & Lensel-Corbeil, 1995; Buchheit, 2008; Buchheit & Laursen, 2013; Denadai, Ortiz, Greco, & de Mello, 2006; Dupont et al., 2010; Wong, Chaouachi, Chamari, Dellal, & Wisloff, 2010), there is a lack of research that compares the tests capable of determining an appropriate speed.

The accurate evaluation of aerobic and anaerobic functions should be optimal during lab conditions (Clarke et al., 2016). The procedures frequently produce a measurement that refers to a specific physiological state, for example, ventilatory or lactate threshold velocity, and velocity at maximal oxygen consumption (VO_2max) or vVO_2max (Billat, 2001). The vVO_2max is defined as the slowest running speed that induces maximal oxygen consumption during a continuous exercise test (Billat & Koralsztein, 1996). Considering the test results as a velocity, rather than as a physiological marker such as the VO_2max, future training could include individualized programming and in-session monitoring.

For example, a programmed session at an intensity of 100% VO_2max is not easily enforced due to the difficulties of measuring the work required. Nonetheless, a programmed session at 100% of the vVO_2max is easily applied due to the distance and implementation time. For example, an interval training session should be designed with a training intensity of 120% of vVO_2max for 15 seconds of work and 15 seconds of passive recovery, repeated for 5 minutes and 2 series.

Although knowledge of the lactate threshold or a direct measurement of VO_2max could be beneficial, many athletes do not have access to these due to the cost, difficulties or time required to take the evaluation. Nonetheless, simple field tests are available for indirectly determining a range of physiological conditions due to the fact that the range of physiological demands during field tests is more suitable for determining the speed produced, such as maximal running speed (MRS), than the vVO_2max (Clarke et al., 2016). When comparing the tests and the MRS registered, the protocol used determines the total physiological stress and, subsequently, the measured physiological condition. For example, intermittent tests are more prone to having a higher contribution of anaerobic energy and to being more appropriate for prescribing supramaximal training sessions (above the vVO_2max). In comparison, continuous tests could be more aerobic and therefore more appropriate for prescribing submaximal training (at or lower than the vVO_2max) (Clarke et al., 2016).

The following points will consider the validity of a series of tests capable of producing an MRS which could be used to program either submaximal or supramaximal endurance training.

These two styles of training (submaximal, at or under the vVO_2 max, or supramaximal, above the vVO_2max) can be used with a wide range of sports, depending on the objectives of the training program and the strengths and weaknesses of the athletes. Traditionally, field tests have been selected based on their ability to reproduce the physiological stress of competition. Nonetheless, not all of the tests are capable of producing an MRS. As a consequence, there is disagreement over whether the following tests can produce an MRS capable of influencing future training programs (Clarke et al. 2016).

3.2.4 Determination of Running Speed in Submaximal and Supramaximal Training

Determining running speed for submaximal training

Tests of time/distance

The *Cooper test* (Cooper, 1968) is a stable, continuous field test in which a treadmill is used to significantly correlate a subject's performance to the VO_2max (O'Gorman et al., 2000). The Cooper test uses a lineal running protocol in which an athlete must maintain the same speed and cover the longest possible distance in 12 minutes (Cooper, 1968). A timed 5 km (3 mile) test is also significantly correlated to the VO_2max using a treadmill (Ramsbottom, Nute, & Williams, 1987), and this justifies the use of time trials or distance tests based on these or similar protocols (Clarke et el., 2016).

The duration of a time trial depends on the time required for generating a maximal aerobic contribution with a reduced level of anaerobic participation. It has been reported that the time needed to reach a system's maximal aerobic stress and to assess the vVO_2max, is 4 minutes 58 seconds (Chamoux, Berthon, & Laubignat, 1996), with an average time for exhaustion at vVO_2max. (Vamax) in the range of 4 to 8 minutes (Billat 7 Koralsztein, 1996, Hill & Rowel, 1996). Significant correlations have also been reported between the vVO_2max, the average velocity of a 5 minute test (v5TT) (Berthon et al., 1997) and a 1,500 meter (4921 ft) test (Lancour et al., 1991). This is why using a traditional test such as the Cooper (12 minute) test could be unnecessary, since the same physiological state can be measured faster (Clarke et al., 2016).

Although there are different types of tests which are based on the amount of time taken to run a certain distance, valid and reliable estimations of vVO_2max can be produced. The evaluation style may require the development of a stimulation strategy (developed through familiarization) for optimal performance (Sheppard et el., 1984). Determining a lineal, continuous MRS may be more appropriate for training styles of a similar nature and, subsequently, for sports such as track and field or similar cyclical type sports. Nonetheless, this training style (cyclical and with a stable velocity) could also be applied to individuals in early stages of training or those possessing a low level of aerobic fitness. The easy-to-use ergometers also provide a wide range of possibilities for athletes with contraindications (such as a recommendation to train in straight lines without a change of direction), and can be useful for contact sports with high injury rates (Clarke et al. 2016).

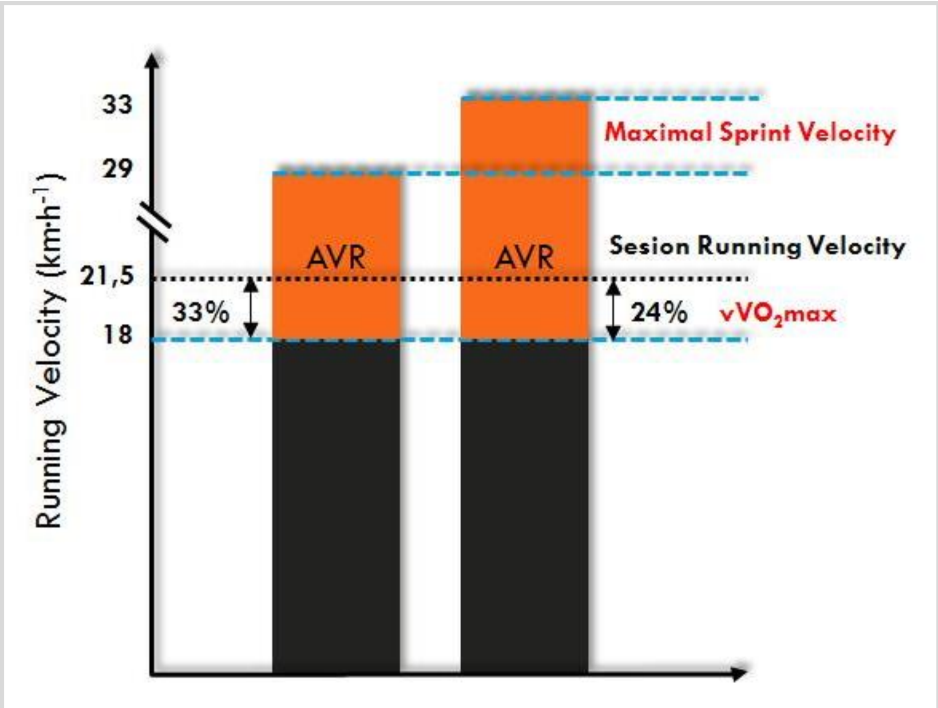
Determining running speed for supramaximal training

Anaerobic Speed Reserve (ASR)

The anaerobic speed reserve (ASR) is the difference between an individual's maximal acceleration velocity and their maximal oxygen consumption speed (vVO_2max or MAS) (Blondel et al., 2001; Bundle, Hoyt, & Weyand, 2003; Dardouri et al., 2014). Having a higher ASR lowers the relative intensity (percentage of anaerobic speed reserve) of exercise over the vVO_2max., thereby lowering the contribution made by anaerobic energy and peripheral fatigue (Bundle et al., 2003; Weyand & Bundle, 2005).

In the illustration, the Anaerobic Speed Reserve (ASR) of two players possessing similar vVO_2max. but different maximal sprinting speeds is shown. During a high intensity interval training session, player B, who has a greater ASR, will work at a lower percentage of his ASR, and will therefore achieve a lower exercise load compared with player A (Buchheit, 2008) (Figure 4). (Del Rosso, 2013a).

Figure 6: Anaerobic Speed Reserve (ASR)



Source: [Untitled image on Anaerobic Speed Reserve]. (Undated). Source: https://goo.gl/dfrgm1.

Nonetheless, during repeated efforts of intensity close to the maximal running speed (maximum acceleration velocity), a high ASR (if due to a low vVO_2max) should be considered to be a negative aspect for performance. For example, it has been reported that an increase in ASR is positively correlated to the fatigue index during repeated accelerations (sprints) on a stationary bike (Mendez-Villanueva, Hamer, & Bishop, 2008). It is likely that a low vVO_2max. causes aerobic energy production to be insufficient to sustain the recovery process between efforts, thus causing fatigue to quickly appear (Clarke et al., 2016). It has also been reported that the ASR alone cannot be used to predict improvements in the average time of repeated sprints (Buchheit & Mendez-Villanueva, 2014), due to the independent change of the vVO_2max. and to the maximum acceleration velocity and its effects on calculating the AVR.

Therefore, although individualized training to the vVO_2max. and a percentage of the ASR should be used to develop anaerobic physical aptitude, ASR registers should not be compared between individuals or be considered in relation to performance without an independent analysis of the vVO_2max and the maximum acceleration velocity (Clarke et al., 2016).

Comparing tests

As discussed earlier, it is likely that intermittent tests have a greater anaerobic energy contribution than continuous tests, and are therefore more appropriate for determining supramaximal training intensities. Supramaximal tests (such as the 30-15 IFT and the YYIRT) produce very different velocities, such as the final MRS, which could have any proportion of the anaerobic speed reserve (ASR) over the vVO_2max. For example, the vIFT is consistently 20-25% quicker than the vVO_2max (Buchheit et al., 2009) and approximately 15-25% greater than the vUMTT (Buchheit et al., 2009).

Significantly higher lactate concentrations have been found during the 30-15 IFT compared to the UMTT, thus demonstrating greater anaerobic energy production (Buchheit et al., 2009). However, this relationship depends on the specific protocols used and could also be affected by the physical aptitude of the individual (Clarke et al., 2016). For example, significant performance differences have not been reported between the YYIRT (level1), vVO_2max (Castagna et al., 2006) or vUMTT (Dupont et al., 2010). Nonetheless, when the MRS was greater than 16.3 km/h, the vUMTT was frequently higher than that achieved in the vYYIRT (level 1) (Dupont et al., 2010), thus showing that the vUMTT and vYYIRT (level 1) are more appropriate for athletes with higher and lower levels of vVO_2max respectively (Dupont et al., 2010).

Comparing the velocities produced during different tests with mainly aerobic energy contributions (submaximal) (Clarke et al., 2016), such as the 5 minute test and the UMTT, there is a slight variation since the protocols represent a similar physiological demand. For example, the UMTT is strongly correlated with the results obtained from the Cooper test (12 minutes) (Leger and Lambert, 1980), the v5TT and the VO_2max treadmill test (Berthon et al., 1997). Nonetheless, when the results were analyzed in detail, the vUMTT was 1.1 km/h faster than the v5TT and approximately 1.4 km/h faster than the vVO_2max. treadmill test (Berthon et al., 1997). This is why individuals with a greater ASR have greater differences between the vUMTT and the vVO_2max. (Leger & Boucher) 1980). This variation may be due to the final sprint method used in incremental tests, which use the final velocity reached as an MRS, so those with a greater ASR may have a greater speed burst during the final stage (Clarke, et al. 2016).

Conclusions

1. Determine which endurance will be evaluated, whether it is general or specific endurance, and, within specific endurance, whether it is technical decision-making or game structure endurance.

2. If the goal is to asses an athlete's general physical aptitude, it would be advisable to lean towards the Yo-Yo test (YYYIRT level 1 and YYIRT level 2).

3. If the goal is to estimate the VO_2max, then the Multi-Stage Fitness Test (20SRT) is a good option. If sufficient space is not available (for example, in basketball) then the UMTT test can also be used.

4. If the goal is to determine the MAS, then the UMTT, 5 minute test or the MAS-EVAL tests are all good choices.

5. If the goal is to prescribe intermittent training, then the 30-15 IFT would be the best option. (Del Rosso, 2013b)

6. If the goal is to prescribe cyclical endurance training with interval methods (between the AT and the VO_2max), then the MAS can be obtained through the UMTT, MAS-EVAL or the 5 minute test.

7. If the goal is to prescribe acyclic endurance training with intermittent methods (velocity> VO_2max), then the work velocity can be obtained through the 30-15 IFT.

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