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Artículo inglés

Effects of a high intensity intermitent exercise on the postural dynamic control of semi pro football players

Efectos de un ejercicio intermitente de alta intensidad sobre el control dinámico postural de jugadores de futbol semiprofesional

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Abstract

The purpose of this research was to study how intermittent high intensity exercise affects dynamic postural control in soccer players of the 3rd Spanish Division. Through an intermittent effort test (Yo-Yo Intermittent test 1) the players are subjected to a fatigue situation in order to observe the incidence of dynamic postural control, whose alteration is related to the increased risk of sports injuries. Fatigue is an element that brings with it a series of physiological changes and makes our motor response ineffective due to the diversity of stimuli offered by a sport such as football, and can trigger in an injury, the epidemiology of football shows us the importance of the control of fatigue and its consequences on the actions of players.

Objective. To verify the incidence of fatigue in dynamic postural control.

Design. Pre experimental, pre and post treatment of a group.

Population. Twelve male players (Age = 4 ± 5.3 years, height = 1.81 ± 0.04 m, weight = 76.8 ± 6.35 , fat% = 11.9 ± 0.99 %)

Method. We performed a pre-test Y Balance Test (YBT), we immediately induce fatigue through Yo-Yo Intermittent test 1, when the player completes the test we obtain lactam sample in blood and perform a post test YBT to see the differences After induced fatigue. Heart rate (HR) was monitored throughout the process to obtain maximum heart rate (HRmax) and the subjective perception of exertion of the players was controlled using Borg scale.

Results. After performing a Student's T, we compared the pre and post means in order to verify if there were significant differences. All the scopes declined in the post-test, but significantly the right frontal range ($p < 0, 0100$), right postero-lateral ($p < 0.0000$) and left postero-medial range ($p < 0.0130$). Pearson's correlation r found positive but not significant relationships between variables.

Conclusion. With the data obtained, we can say that fatigue induced through a test of high intermittent intensity adversely affects the dynamic postural control, even leading to situations of risk of injury, such situations appear in the frontal plane where the leg more Affected was the right (skillful or non-stabilizing), which significantly worsened and became risky after fatigue ($p < 0.01$). We can say that the skillful leg in this case is the less stable leg.

Keywords

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Dynamic Postural Control; YBT; Fatigue; Yo Yo Intermittent Test 1; Soccer

Resumen

El propósito de esta investigación fue estudiar cómo afecta el ejercicio intermitente de alta intensidad al control dinámico postural en jugadores de fútbol de 3ª División Española. A través de un test de esfuerzo intermitente (Yo-Yo Intermittent test 1) se somete a los jugadores a una situación de fatiga con el objeto de observar la incidencia en el control dinámico postural, cuya alteración está relacionada con el aumento del riesgo de las lesiones deportivas. La fatiga es un elemento que trae consigo una serie de cambios fisiológicos y hace ineficaz nuestra respuesta motriz ante la diversidad de estímulos que ofrece un deporte como el fútbol, pudiendo desencadenar en una lesión, la epidemiología lesional del fútbol nos muestra la importancia del control de la fatiga y sus consecuencias en las acciones de los jugadores.

Objetivo. Comprobar la incidencia de la fatiga en el control dinámico postural.

Diseño. Pre experimental, de pre y post tratamiento de un grupo.

Población. Doce jugadores varones (Edad = $4\pm 5,3$ años, altura = $1,81\pm 0,04$ m, peso = $76,8\pm 6,35$, % grasa = $11,9\pm 0,99$ %)

Método. Se realizó un pre test Y Balance Test (YBT), inmediatamente inducimos fatiga a través de Yo-Yo Intermittent test 1, cuando el jugador finaliza el test se obtiene muestra de lactemia en sangre y se realiza un el post test YBT para ver las diferencias tras la fatiga inducida. La frecuencia cardiaca (FC) se monitorizo durante todo el proceso para obtener la frecuencia cardiaca máxima (FCmax) y se controló la percepción subjetiva de esfuerzo de los jugadores mediante escala de Borg.

Resultados. Tras realizar una T de Student comparamos las medias pre y post con el objetivo de comprobar si existían diferencias significativas. Todos los alcances descendieron en el post test, pero de forma significativa fueron el alcance frontal derecho ($p < 0,0100$), postero-lateral derecho ($p < 0,0000$) y postero-medial izquierdo ($p < 0,0130$). La correlación r de Pearson encontró relaciones positivas aunque no significativas entre variables.

Conclusión. Con los datos obtenidos, podemos decir que la fatiga inducida a través de un test de alta intensidad intermitente afecta de forma negativa al control dinámico postural, llevándolo incluso, a situaciones de riesgo de lesión, esas situaciones aparecen en el plano frontal donde la pierna más afectada fue la derecha (hábil o no estabilizadora) que empeoró de manera significativa entrando en situación de riesgo tras la fatiga ($p < 0,01$). Podemos decir que la pierna hábil en este caso es la pierna menos estable.

Palabras clave

Control dinámico postural; YBT; fatiga; Yo Yo Intermittent Test 1; Fútbol

Introduction

The game of football is intermittent in nature, and playing it produces a series of harmful alterations in the body over time, specifically as regards intrinsic factors that produce ineffective responses in different situations of play. These responses are the main cause of injury in football, one of the sports that result in the most injuries in the world, hence the importance of this study. The damaging mechanics are the result of bad motor responses caused by a bad dynamic postural control (DPC). Defined as the capacity of an individual to maintain the stability of the centre of mass during movement, DPC an element that should be examined in relation to the risk of sports injury⁽¹⁾. DPC is performed by the sensorimotor system, which functions via 3 subsystems (visual, vestibular and proprioceptive systems). It is thanks to these systems that we are able to receive information and generate a motor response, which may be retroactive (response to an unexpected stimulus) or anticipated (previously learnt)⁽²⁾. The collateral effect of a failure in DPC is injury. This is because, when taken in conjunction with the intermittent nature of the sport, it creates an increased risk of injury. The risk appears towards the end of the match and has major epidemiological consequences^(3, 4, 5, 60).

All this leads us to ask the following question: How much does high-intensity intermittent exertion affect the dynamic postural control of football players? Taking this question as a starting point, we developed the following hypothesis: 'High-intensity intermittent exercise (Yo-Yo Intermittent Recovery Test 1) reduces dynamic postural control, where DPC is the dependent variable and intermittent exercise is the independent variable.

What causes these harmful alterations during play? Fatigue. In other words, any exercise-induced reduction in the ability to exert muscle force or power, regardless of whether or not the task can be sustained ⁽⁷⁾. This manifests itself on two levels. Firstly, fatigue can be central, due to an inadequate activation of the motor neurons in the CNS ⁽⁷⁾. This type of fatigue causes most controversy among researchers as it refers to alterations in brain function. Secondly, it can be peripheral, with peripheral fatigue defined as the failure of one or more of the processes involved in the motor unit. This principally occurs within the muscle, but there are also components related to the neuromuscular junction ⁽⁸⁾.

Fatigue is multifactorial in nature and the mechanisms involved are imprecise, although there are many indicators (Ca, Na, Pi, EMG, Neurotransmitters, etc.). We focused on those we were able to quantify directly - lactate, HRmax and RPE - to ensure that the players surpassed the general fatigue thresholds established in the bibliographical literature.

The criteria for inclusion in the study were to be a player in the first team of El Palo Football Club, competing in Spain's 3rd Division in the 2015/16 season, being over 18, and being familiar with the YBT. The exclusion criterion was having had an injury in the 6 months between the start of the season and the end of the study. The players signed a consent form that explained the study in detail and was used to formalise their participation. This form had previously been approved by the University of Wales. The study adheres to the basic principles of the World Medical Association's Declaration of Helsinki.

There are several other studies with a similar structure, but which follow different methodologies. These include studies in other sporting contexts and, in many cases, the levels of exertion do not come close to the real situation of play in the respective sports.

Methodology

The participants were a group of 20 football players belonging to a 3rd division team from Malaga, of which 12 remained after 6 were lost through experimental mortality. The inclusion criteria were: the absence of injury over the previous 6 months from the beginning of the season, age 18+, part of the first team, and familiarity with the YBT. To formalise their participation, they were given a consent form with detailed information of the study they were taking part in.

Table 1. Studies with a similar structure.			
AUTHOR	DESCRIPTION	INSTRUMENTS	
		DYNAMIC POSTURAL CONTROL	FATIGUE
Enda Whyte et al (2015)	Dynamic control pre-test + Fatigue protocol + Dynamic control post-test	SEBT	High-intensity intermittent circuit
Sarshin et al (2011)		YBT	6 functional strength exercises
Sarshin et al (2012)		YBT	Conconi test
Steib S el al (2013)		SEBT	Incremental treadmill test
Gribble PA (2004)		SEBT	Isokinetic fatigue protocol
Gribble PA (2009)		SEBT	Isokinetic fatigue protocol
Sarshin et al (2007)		SEBT	Strength circuit (20 min 7 stations)

Procedure

The following data was recorded: age, weight, % body fat, dominant leg, and hip-ankle length. 11 days later, a maximal test was performed (Yo-Yo Intermittent Recovery Test 1) to obtain the players' HRmax and familiarise them with the test. This process lasted 6 days. Having obtained all the data, the evaluation was performed 8 days later (pre-test YBT + Yo-Yo Intermittent Recovery Test + post-test YBT) and lasted 10 days.

SCHEDULE	
DATE	PROCEDURE
02/12/2015	Informed consent and explanation of the programme
10/12/2015	Record age, weight, height, % body fat, dominant leg, and hip-ankle length
21 to 27/12/15	Pre-test (Yo-Yo Intermittent Recovery Test 1)
04/01/2016	Pos-test (Pre-YBT + Yo-Yo Intermittent Recovery Test + Post-YBT)

Prior evaluation

The first step was to take measurements: resting heart rate, weight, height, age, % body fat, dominant leg, hip-ankle length. The % body fat and weight measurements were made by a qualified external analyst with experience of more than 2,000 sample subjects. The players were subjected to an initial high-intensity intermittent maximal test, to establish HRmax values and perceived exertion scale. Additionally, the test indirectly gave us the speed in m/s, the time in seconds it took to complete the 40 m interval, the total distance (m), and VO2 Max.

Pre-Test

The players began with a warm-up of 10 minutes joint-mobility exercises and several running drills. After the warm-up they did a pre-test YBT and we recorded the first reach results. As soon as each player finished the YBT, he joined the group warm up.

Test

After the group warm-up (20 min), we began the Yo-Yo Intermittent Recovery Test 1 ⁽⁹⁾. When a player exited the test, we waited 1 minute before performing the blood lactate test and recording the results.

Post-test

After obtaining the lactate results, we quickly moved to the physiotherapy room 5 metres away. Here the player took off his boots without sitting down and performed the post-test YBT. The total time lapsed from the end of the Yo-Yo test to the beginning of the post-test YBT was 80 seconds.

Y Balance Test

This is a practical assessment tool that gained popularity in clinical and research fields as a way of evaluating motor function ⁽¹¹⁾

The test kit consists of three PVC pipes, joined at a central point and radiating out in the anterior, posteromedial and posterolateral directions; the directions of the reaches. The posterior pipes are 135° from the anterior pipe, with 90° between the posterior pipes. Each pipe is marked at 5-millimetre intervals for measurement.

The subject is asked to push the reach indicator along the pipe as far as possible with his foot while maintaining a base of support with the other leg, and flexing the hip, knee and ankle joints of this support leg. Once he has reached the maximum distance, he must return his foot to its original position while maintaining balance and using the force and muscular control of the support leg ⁽¹²⁾. The goal is for the individual to establish a stable support base and maintain it while stretching to maximum reach with the other limb. The idea is to determine how far a player can reach with one leg while maintaining a support base with the other. ⁽¹²⁾.

The learning effect

3 trials are performed in each direction to avoid 'the learning effect'. The player then has 3 more attempts, the results of which are recorded. We did not do any prior familiarisation exercises with the players, as they were already familiar with the protocol, having used it during the current season and part of the previous one. Therefore we considered this aspect to have been dealt with. When the evaluators have been trained by an experienced evaluator, this test is highly reliable ⁽¹²⁾.

The subject wears socks, but no shoes, and puts the toes of his support leg on the red line. We first tested the right leg in all 3 directions and then we tested the left leg. ⁽¹²⁾. The directions are as follows.

When was a reach trial considered invalid?

A reach trial was considered invalid if the player could not maintain the unilateral position, put his foot on the indicator while moving it, lost contact with the indicator while it was moving, or did not return the reach foot to its initial position.

Composite reach

In order to calculate Composite Reach (CR), which is an overall score for each leg for all 3 reach directions, the player adopts the supine position ⁽¹³⁾ and the length of the support leg from the anterior superior iliac spine to the most distal point of the medial malleolus is measured using a standard tape measure ⁽¹²⁾. The formula is the sum of all 3 reach directions for one leg, divided by 3 times the distance between the hip and ankle, multiplied by 100. This allows us to normalise the reaches of each leg, giving it a single value correlated with the length of the subject's lower limb

What did we measure?

This allowed us to evaluate dynamic balance, which can be defined in the terms of ⁽¹⁴⁾ as the ability of an individual to maintain stability of the centre of mass during movement; as an inherent component of many sporting activities, this is an important construct to examine in relation to injury risk.

What is the protocol?

3 trials are performed prior to the evaluation of each reach to overcome the 'learning effect' ⁽¹²⁾. We followed this protocol, but the exercise also forms part of the players' motor programme as the daily warm-up includes the same movements. After this short warm up, we first evaluated the 3 reaches of one leg and then the 3 reaches of the other. When collecting the data, we had to determine two scores: the average and the maximum. For the maximum score, we used the maximum distance reached in the 3 attempts in each direction and in the CR.

Asymmetries

These are defined as the difference between one limb and the other as regards a specific reach (frontal, medial, lateral). The authors of most renown in this area ^(10,11), establish the following scores related to the risk of injury:

- For the Frontal reach, ≥ 4 centimetres is considered an injury risk factor (2.5 times more likely).
- For the medial and posterolateral reaches, ≥ 6 cm is considered a risk factor.

When interpreting the results of the test, it is important to look at the amplified left/right asymmetry instead of simply a reduction in general performance.

High-intensity intermittent test (Yo-Yo intermittent recovery test 1)

This test was inspired by Léger's multi-stage fitness test (Pacer Test, or Beep Test). The test consists of 2×20 m shuttle runs that increase in speed and have 10-second recovery breaks between them. The subjects run until they are unable to maintain the speed cover the distance ⁽¹⁵⁾.

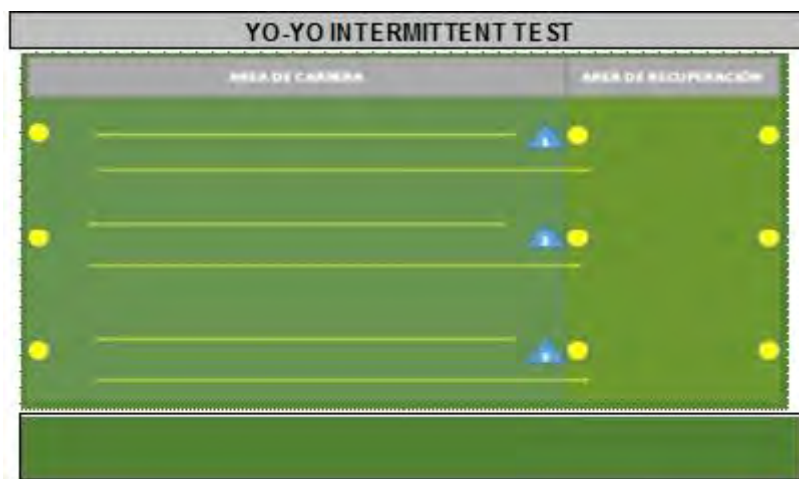


Figure 1. Graphic representation of Yo-Yo Test 1.

How does it work?

The start of the run and the arrival at the cones are signalled by beeps. Subjects start on one beep and must reach the cone before the next beep. They decelerate in the recovery zone and have 10 seconds to rest. The intervals become increasingly shorter and more intense, but the recovery time remains the same.

The test starts at a low speed and then gradually the speed increases. For a fit and practised individual, Yo-Yo Intermittent Recovery Test 1 lasts 10-20 minutes. The test focuses on the ability to do intermittent exercise that produces maximum activation of the aerobic system ⁽¹⁵⁾. The test has also proven to be sensitive to changes in the performance of maximum oxygen uptake ⁽¹⁵⁾.

Validity and reliability

We know that at the end of the test, the participants reach their VO₂ max. The theoretical VO₂ max was positively correlated by ⁽¹⁵⁾ in a study of 141 subjects. He observed a correlation between VO₂ max and the Yo-Yo Test $r=0.70$ (it is almost 1) with significance (< 0.005) (which was normal due to the large size of the sample). It can be calculated using the following equation: $(VO_2\max \text{ (mL/min/kg)}) = IR1 \text{ distance (m)} \times 0.0084 + 36.4$.

The test can be used to quickly determine the maximum heart rate of an individual. For this reason we used it as an initial maximal test to estimate the *real* maximum heart rate of the players, which sometimes does not coincide with the *theoretical* maximum heart rate, and to ensure that the exertion obtained in the tests reached the required thresholds and

generated the fatigue we were seeking. HRmax is obtained after 6 minutes; in other words, the test provides the relevant information if it is long enough (> 6 min) ⁽¹⁵⁾.

Furthermore, the reliability and validity of Yo-Yo test level 1 are well known, and strong correlations have been found, for example, between the performance of the Yo-Yo test and the amount of high-intensity running during a football match ⁽¹⁵⁾.

Results

The presentation of data focuses on comparing the absolute scores of the pre-test and post-test. Through this comparison we get the following results.

1. Composite Reach

The percentage averages for the right leg in the pre-test and post-test were:

- Right leg (0.96% and 0.91%): 0.05% difference.
- Left leg (0.96% and 0.93%): 0.03% difference.

After the induced fatigue, we found that the right leg, or dominant leg, was most negatively affected overall.

2. Maximum reaches

The YBT results showed a reduction in the maximum reach distances after fatigue in all directions (FRONT, LAT, MED).

Left leg (stabilising, non-dominant) This leg reached the farthest and was least affected by fatigue.

Table 3. Left leg reach distances.			
REACH	PRE	POST	DIFF
Anterior	65.25	63.08	2.17
Posterolateral	102.9	99.5	3.4
Posteromedial	107.5	104.2	3.3

Right leg (dominant) This leg reached lower maximum distances both before and after fatigue, in other words, it was worse beforehand and most affected by fatigue. It only had better reach in the posterolateral pre-test.

Table 4. Right leg reach distances.			
REACH	PRE	POST	DIFF
Anterior	65.00	61.00	4.00
Posterolateral	104.00	97.00	7.00
Posteromedial	107.00	104.00	3.00

3. Asymmetry

Pre-Test

Table 5. Pre-test asymmetry for different reaches.

PRE-TEST		
REACH	ASYMMETRY (cm)	OBSERVATIONS
Anterior	4.00	Risk factor only with anterior reach (≥ 4 cm)
Posterolateral	3.75	
Posteromedial	4.42	

Post-test

Table 6. Post-test asymmetry for different reaches.

POST-TEST		
REACH	ASYMMETRY (cm)	OBSERVATIONS
Anterior	5.25	Asymmetry increased in all reaches
Posterolateral	3.83	
Posteromedial	4.75	

Asymmetry by planes

Table 7. Pre-test and post-test frontal plane asymmetry.

FRONTAL ASYMMETRY					
PRE-TEST			POST-TEST		
Right	Left	Diff	Right	Left	Diff
65.42	65.25	4	61.33	63.08	5.25

Table 8. Pre-test and post-test posteromedial plane asymmetry.

POSTEROMEDIAL ASYMMETRY					
PRE-TEST			POST-TEST		
Right	Left	Diff	Right	Left	Diff
106.58	107.5	3.75	103.83	104.17	3.83

Table 9. Pre-test and post-test posterolateral plane asymmetry.

POSTEROLATERAL ASYMMETRY					
PRE-TEST			POST-TEST		
Right	Left	Diff	Right	Left	Diff
103.83	102.92	4.48	96.58	99.5	4.75

4. Lactate

In the post-test, after the induced fatigue, an average of 13.9 ± 0.7 mmol/l was recorded for the group.

Table 10. Post-test lactate	
mmol/L lactate values recorded for the players from highest to lowest	LACTATE (mmol/L)
	14.3
	14.3
	14.6
	14.3
	14.8
	14.4
	14.2
	14.6
	14.5
	14.3
	14.8
	14.2
13.5	
AVERAGE	13.91

5. Yo-Yo Intermittent Recovery Test 1

Post-test.

Overall, the group exited the test at level 22, 27 ± 1.45 . Half the players ended the test at level 23. The average speed was 5, 13 ± 0.18 m/s, the total distance $3.163.33 \pm 392.09$ m and the VO_{2max} 63.58 ± 3.33 ml/min/kg. They managed to reach a very high average in the test.

Table 11. Post-Test Yo-Yo Intermittent Recovery Test 1						
	Subject	Level	Speed (m/s)	Time 40 m (sec)	Total distance (m)	VO_{2max} (ml/min/kg)
LOWEST SCORES	1	20.00	4.86	8.23	2680.00	59.98
	2	20.00	4.86	8.23	2680.00	59.98
	9	20.5	4.86	8.23	2560.00	57.9
	8	21.6	5.00	8.00	2920.00	60.93
	11	22.1	5.14	7.78	3040.00	61.94
	10	22.1	5.14	7.78	3040.00	62.94
HIGHEST SCORES	5	23.2	5.28	7.58	3400.00	66.32
	7	23.2	5.28	7.58	3400.00	66.32
	12	23.4	5.28	7.58	3440.00	66.67
	4	23.5	5.28	7.58	3520.00	65.97
	3	23.8	5.28	7.58	3640.00	66.98
	6	23.8	5.28	7.58	3640.00	66.98
	AVERAGE	22.27	5.13	7.81	3163.33	63.58

6. Heart Rate (HR)

As regards the maximum heart rate, in the initial evaluation the average values for the group were 186.9 ± 9.46 bpm and in the post-test the average values for the group were 187.3 ± 9.04 bpm. The resting HR was 60.6 ± 2.84 bpm and the HR Reserve was 126.8 ± 8.3 bpm.

Table 12. Pre-test and post-test heart rate.

Subject	Resting HR (bpm)			HRmax (bpm)			HR Reserve (bpm)		
	INITIAL	POST	DIFF	INITIAL	POST	DIFF	INITIAL	POST	DIFF
1	62	61	1	200	198	2	138	137	2
2	61	61	0	200	200	0	139	139	0
3	62	63	1	186	193	7	124	130	7
4	62	60	2	178	188	10	116	128	10
5	62	61	1	180	180	0	118	119	0
6	64	6	2	188	189	1	124	127	1
7	64	64	0	176	178	2	112	114	2
8	62	62	0	182	182	0	120	120	0
9	68	64	4	201	200	1	133	136	1
10	57	57	0	183	175	8	126	118	8
11	56	56	0	193	188	5	137	132	5
12	56	56	0	176	177	1	120	121	1
AVERAGE	61.3	60.6	0.9	186.9	187.3	3.1	125.6	126.8	3.1

7. Rate of Perceived Exertion (RPE)

In the initial evaluation, the RPE was 19 ± 0.9 . While in the post-test it was 19.4 ± 0.9 .

Normality test (Kolmogorov-Smirnov test)

The sample group participating in this study was categorised as normal, given that in the Kolmogorov - Smirnov test all the pre-test and post-test reach distances and asymmetries had normal values ($p > 0.005$).

Student's t-test for pre-test YBT and post-test YBT (after fatigue)

This is the decisive test of the study, as its design requires us to make a comparison of the pre-test and post-test averages of related measurements – where ($p < 0.05$) in many cases. The post-test values were higher than the pre-test values and, in terms of YBT scoring, this is considered to reflect low levels of dynamic postural control after fatigue. We compared the pre-test and post-test averages to determine whether there were any significant differences. All the reach distances were lower in the post-test, but most significantly in the right frontal reach ($p < 0.0100$), right posterolateral reach ($p < 0.0000$) and left posteromedial reach ($p < 0.0130$).

Correlations

We performed Pearson's r correlation test. We found no significant relationships between the variables. However, in the differences between the YBTs, we found some disparate results in the directions in the post-test.

Discussion

We achieved our objective for this study since, in light of the data obtained, we can safely say that the postural dynamic control of the football players was reduced after high-intensity intermittent exercise, thereby partially complying with the suggested hypothesis. This is in keeping with authors such as ^(10, 16) in the study of YBT ^(17, 18, 19) using other instruments.

The most pronounced asymmetry was in the frontal plane, where the right leg (dominant, or non-supporting leg) was the most affected. This leg worsened significantly after the fatigue ($p < 0.01$). This negative effect is possibly due to the influence of fatigue on neuromuscular control strategies, in our case, induced by a high-intensity intermittent test ^{(20, 21,}

22, 23). As we can see, the reduction in maximum reach distances shows the negative effect of fatigue and the reduction of asymmetries demonstrates the risk of injury.

Maximum reach distances

All the maximum reach distances (left/right) and HR dropped, in keeping with studies of a similar structure.

These changes in control strategies may get worse on the pitch, as we know there are two types of strategy, retroaction and anticipation ⁽²⁾. In the YBT, the motor response is through anticipation (the players predict the balance required because they know exactly how to do the YBT), as it is already installed in their the motor programme. However, on the pitch many of the stimuli present situations where the motor response is produced through retroaction, in other words, in response to unexpected situations, which are the ones that cause injuries.

Left leg

This leg was least affected, as it is the stabilising leg (there was only one left-footed player), in other words, the leg which acts as a stabiliser in most circumstances in the game (kicking, jumping, bumping into other players, etc.). It is, therefore, logical to think it has more integrated adaptations than the other leg for the dynamic unipedal control situations that the YBT subjects it to. The worst reach distances were the posterolateral and posteromedial reaches, with almost the same degree of reduction. The latter was, moreover, statistically significant ($p=0.009$). This was in keeping with the composite reach of the left leg, which was reduced by 0.3%. Therefore the fatigue also affected the left leg. The main muscles employed in these reaches were the biceps femoris, the gluteus, and the tibialis anterior ⁽¹³⁾, which is curiously the most-injured muscle in football ⁽⁶⁾.

Right leg

The maximum reach distances decreased more in the right leg, especially in the anterior and posterolateral reaches where the pre-test/post-test difference was significant: ($p<0.01$) and ($p<0.0000$). This is probably because in its capacity as the dominant leg, the right leg is not used to situations of unipedal activation as a stabiliser, which is why the reach distances were lower in the YBT.

In a game like football, where there is so much uncertainty and so many factors are involved, when this leg has to take on the dynamic control of the body it is more likely to be inefficient, and the inefficient motor response can lead to situations of risk. There are many situations in football that occur in the frontal plane in dynamic unipedal equilibrium (a tackle to steal the ball, controlling a bad pass, etc.). The most active muscles in this activity are the vastus medialis and the vastus lateralis ⁽¹³⁾.

Asymmetries

This is the most important value from an injury point of view ⁽¹³⁾. We can highlight the frontal reach, as all were asymmetrical to begin with, before starting the test. Age was a differential component, with the young players being more asymmetrical than the older players prior to the induced fatigue. The situation worsened after the fatiguing stimulation, but in this case it was the older players who were the most affected.

In conclusion, we have some players with a risk factor in frontal asymmetry, with the right leg being most affected. These players are 2.4 to 3.8 times more likely to suffer an injury ^(14, 11)

FCM, Borg , VO2 max and lactate

Our players recorded excellent results, which was not surprising as they ended the test at level 22.3 ± 1.45 (it goes as far as 23.8) with an average HRmax of 187.3 ± 9.04 . The results proved fatigue, as they were the same maximum levels reached in the initial test used to determine HRmax. This is a very reliable value, as we know that HRmax remains constant in the short term, only changing slightly each year⁽²⁴⁾. Furthermore, it was measured using a maximal test, which is one of the most accurate ways of quantifying it.

Our RPE was 19.4 ± 0.9 , and we had to bear in mind that a sensation of 15 or more is related to 80% VO2 max^(25, 26, 18, 27) and that the test used is very reliable for stimulating it⁽¹⁵⁾, so the VO2max recorded for our subjects was higher, they reached a VO2max of 63.26 ± 4.68 ml/min/kg. The average VO2max load in a professional football match oscillates between 75% and 85% of maximum oxygen uptake^(28, 29, 30) with no major differences between categories and positions. In other words, our players easily passed the thresholds in the test, especially bearing in mind the correlation between HRmax values and VO2max values⁽³¹⁾. In summary, our RPE and VO2max surpassed the other studies, reaching similar or greater thresholds than those of professional competition. Another favourable indicator of the fatigue generated.

Our values are similar to those in the thesis⁽³²⁾, which recorded the results of 1612 third-division players. They obtained an average of 189.6 ± 3 bpm in official matches and 181.4 ± 12.2 bpm in training. We can see that our players' exertion is very similar to that of a competition in the same category, and greater than that of a training session. Our results are also in keeping with the fatigue and dynamic control studies of⁽¹⁶⁾, which recorded RPEs of 17 and 19.5 respectively, with similar heart rate levels of 190 ± 5.5 and 194.3 ± 8.2 . Together with the previous paragraph, this justifies the indicators that comprise the variables which make up 'fatigue'.

Lactate

The levels of lactate reached were 13.9 ± 0.7 mmol/l, another strong indicator of the reported fatigue, as we know that during football matches the concentrations of lactate observed are between 2 and 10 mmol/l, with individual values above 12 mmol/l^(28, 29, 18, 15). It is also known there is a causal relationship between the anaerobic metabolism and muscular fatigue which causes a reduction in contractile function. We were able to observe that this particularly affected the anterior reach in the YBT. We did not find any significant differences between lactate and age, as all of players had similar values.

Dynamic postural control, fatigue and injury prevention

Regarding the differences in force between the dominant and non-dominant legs, the opinion of different authors is very diverse⁽³²⁾.

Explosive players have a predominance of rapid fibres, which are able to generate more mechanical tension in muscles and ligaments, and have a high glycolytic capacity that leads to high concentrations of lactate, as we can see in the results⁽²⁾.

In the anterior reach the most important and active muscles are the vastus medialis and the vastus lateralis⁽¹³⁾. However, it is important to remember that the posterolateral reach distance also decreased significantly in both legs post-test, although they did not enter a situation of risk. In these reaches the main muscles involved are the biceps femoris, the gluteus and the tibialis anterior⁽¹³⁾, and the lack of force in one area can be compensated by another. In high-speed action, fatigue can cause the hamstrings to lose strength and the quadriceps to take on the dominant role, which is why they were most negatively affected in the test. An imbalance in the functional hamstring/quadriceps (H/Q) ratio⁽³⁴⁾ is considered to be one of the major causes of injury in football.

We know that high-intensity, fatigue-inducing exercises lead to tibial anteriorisation, genu valgum, and a decrease in the angle of joint flexion. A joint that is able to flex further is a more protected joint. It helps activate the quadriceps, and there is less risk of injury. A more flexible knee involves greater rotating components, in other words, more safety when changing direction, and changes of direction are constant in the test. The downward movements in the anterior reach depend on a good plantar, knee and trunk dorsiflexion⁽¹³⁾, which was evidently not apparent in the post-test YBT, further demonstrating the risk of injury.

The changes in direction in the test produce a very predominant eccentric action of the quadriceps. In our case, there was 1 change of direction in each interval and, if most of the players stopped around level 22, that means they made 94 changes of direction in a context of intermittent intensity. The reduction in reach direction and the frontal plane asymmetries in the YBT are, therefore, more than proven due to a lack of good quadriceps flexion, and possibly all derived from an imbalance in the Q/H functional ratio.

Having a less-stable leg can alter the way in which the footballer reacts to a situation, leading to an increase in tension in the more-stable lower limb. A less-stable limb, or even an injury, can be masked by the stability of the opposite limb, hence the importance of this test⁽¹³⁾, as we evaluate the limbs separately and can see where the imbalance stems from. It is important to bear in mind that in this sport, on a gestural level (knocks, tackles, jumps, bangs, etc.), most situations occur in dynamic unipedal equilibrium, which makes it even more advisable to use and integrate the test into the team's routine. The test only takes around 3 minutes per player to complete, and is not at all expensive when compared to the information it provides.

The results of our study contribute to a better understanding of the value and quantification of fatigue as regards the dynamic balance of football players and associated risk factors.

Conclusion

The data obtained tells us that fatigue induced by means of a high-intensity intermittent test negatively affects dynamic postural control, and can even lead to a risk of injury. This risk appears in the frontal plane where the right leg (dominant or non-stabilising leg) is most affected. The results showed significant deterioration in this leg, which entered a situation of risk after fatigue ($p < 0.01$). We can say, therefore, that in this case the dominant leg is the least stable.

In order to improve the situation, we need to implement strength work and unilateral coordination, eccentric H/Q ratio work (quantifying players' levels of agonist/antagonist muscle strength with the use of linear encoders or isokinetic devices). A good core workout or lumbopelvic stabilisation is essential to ensure that the transmission of impulses to the different sections is efficient.⁽³⁶⁾ The work should be done when fatigued, as the majority of injuries occur at the end of the match^(28, 29, 5), when the neuromuscular system is more fatigued, leading to compensatory strategies that result in injuries. This is why I believe that if we wish to get good results we must do the work in similar conditions, ensuring it can be more readily transferred to real situations.

This type of test (YBT) is needed in football, as it is a sport that excessively overloads the lower body. We use our legs to both run and move the ball, and the nature of the sport itself fosters asymmetry. The test as a tool is very accessible from an economic point of view, and it allows us to accurately quantify and determine asymmetry, as well as being backed by extensive scientific evidence.

For future research, it would be advisable to include a video analysis, to evaluate the angles of execution and pre-/post-test compensatory activity, and to include the use of EMG to obtain specific information about electrical activity.

Last but not least, it would be interesting to perform the pre-test and post-test in official matches, in other words, after real fatigue, rather than induced fatigue.

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