

Carrasco, L.; Espinar, J.; Carbonell, F.J.; Martínez-Díaz, I.C. (202x) Local and General Fatigue: Effects on Knee Proprioception in Soccer Players. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. x (x) pp.xx Pendiente de publicación / In press.

ORIGINAL

LOCAL AND GENERAL FATIGUE: EFFECTS ON KNEE PROPRIOCEPTION IN SOCCER PLAYERS

FATIGA LOCAL Y GENERAL: EFECTOS SOBRE LA PROPIOCEPCIÓN DE RODILLA EN FUTBOLISTAS

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Código UNESCO / UNESCO code: 241118 Fisiología del Movimiento / Physiology of movement

Clasificación Consejo de Europa / Council of Europe classification: 14: Fisioterapia y rehabilitación / Physiotherapy and rehabilitation.

Recibido 29 de julio de 2019 **Received** July 29, 2019

Aceptado 1 de mayo de 2020 **Accepted** May 1, 2020

ABSTRACT

The aim of this study was to contrast the effects of two different types of fatigue, local and general, on knee proprioception. Twenty two male amateur soccer players were evaluated on isokinetic dynamometer before and after exercise-induced both local and general fatigue. This evaluation consisted of an active knee repositioning test, in which mean absolute and relative deviations regarding target angle (30° knee flexion) were assessed. The proprioceptive capacity of the subjects was affected by induction of both types of fatigue only when mean absolute error was estimated; however, no statistical differences were found between them. In conclusion, and regardless of their type, fatigue induced to these players seems to influence the proprioception of the knees although this effect is dependent on the type of angular error that is considered.

KEYWORDS: proprioception, joint repositioning test, fatigue, knee, soccer.

RESUMEN

El objetivo del presente estudio fue contrastar los efectos de dos tipos de fatiga, local y general, sobre la propiocepción de la rodilla. 22 jugadores semi-profesionales de fútbol, fueron evaluados en un dinamómetro isocinético antes y después de realizar esfuerzos que indujeron fatiga muscular local así como fatiga general. Dicha evaluación se basó en la prueba de reposicionamiento angular activo de la rodilla, registrando las desviaciones absolutas y relativas respecto al ángulo diana (30° de flexión). La inducción de ambos tipos de fatiga consiguió alterar de forma significativa la capacidad propioceptiva de los sujetos tras valorar únicamente el error absoluto, si bien no se observaron diferencias significativas en su contraste. En conclusión, e independientemente de su tipología, la fatiga inducida a estos futbolistas parece influir sobre la propiocepción de sus rodillas, aunque este efecto está condicionado por el tipo de error angular que se considere.

PALABRAS CLAVE: propiocepción, test de reposicionamiento, fatiga, rodilla, fútbol.

1 INTRODUCTION

Soccer is characterized by being a contact sport that involves constant high-intensity efforts, skilful actions with the ball, explosive movements and disputes with the opponent, among other actions. The combination of these and other external factors provokes that players are constantly and inevitably exposed to high injury risk (Adalid, 2014). The appearance of injuries is an aspect that increasingly worries both soccer players themselves and sports clubs due to many different factors; playing downtime (each player loses an average of 35 training sessions and 4-8 soccer matches a year due to injuries), loss of physical fitness due to inactivity, economic losses (reaching an average of 144,000 euros per player and 3,587,000 euros per team in one season) or possible fears when facing future situations similar to those that caused the injury (Ortega, Argemi, Batista, García, and Liota, 2006). For this reason, an increasing number of studies are focused on injury prevention and rehabilitation strategies to minimize the influence of all these factors that affect soccer performance.

In any case, and considering the anatomical regions most frequently affected, the ankle joint shows the highest incidence of injury (20.4% of all seasonal injuries), followed by knee and thigh injuries (17.7% and 14.5%, respectively). Despite this, some authors insist that most of these injuries are located in the knee joint (Llana, Pérez, and Lledó, 2010) these being the most serious injuries, so the disabling period may be greater (Peterson, Junge, Chomiak, Graf-Baumann, and Dvorak, 2000).

Regarding their etiology, knee injuries are associated with both intrinsic risk factors (previous injuries, inadequate rehabilitation, conditional and technical

capacities, genetics, morphology, performance level and psychological factors) and extrinsic risk factors (weather, soccer field surface, sports equipment, etc.). In addition, alterations or deficits in the sensorimotor system, postural control, muscle activation, anticipation mechanisms and, in general, alterations in proprioceptive ability are other factors of consideration (Fort and Romero, 2013).

Proprioception is the part of the somatosensory system responsible for obtaining sensitive information and sending it to the central nervous system (CNS) in order to control the state of different body segments concerning others (Biedert, 2000). Thus, it is not surprising that proprioceptive training is increasingly included in soccer injury prevention and rehabilitation programs. However, one of the factors that can directly affect the proprioceptive ability of soccer players and, therefore, to increase the risk of injury is fatigue. A number of joint and muscle injuries occur near the end of the match, especially in the lower limbs (Augustsson et al., 2006; Bazneshin, Amiri, Jamshidi, and Vasaghi-Gharamaleki, 2015). In this regard, previous studies have shown controversial results, since some of them have found an alteration of proprioception due to fatigue (Vuillermé and Boisgontier, 2008; Bayramoglu, Toprak, and Sozay, 2007), and others have not found this effect (Gurney, Milani and Pedersen, 2000; South and George, 2007; Miura et al., 2004). The study of different populations (with different training level), the analysis of different joints (mainly knee and ankle), the induction of different forms of fatigue and the use of different evaluation tests of proprioceptive ability could explain the lack of concordance between studies (Bazneshin et al., 2015). In this case, the fatigue experienced by soccer players during training sessions and competition is both general, affecting different organ systems, and local, affecting mainly the muscles of lower limbs. On the other hand, different tests can be used in the proprioceptive evaluation, among which stand out the passive movement detection threshold test, the sense of muscle tension test and the active joint position sense assessment (Torres, Vasques, Duarte and Cabri, 2010). These tests evaluate different areas of proprioception, since they are based on joint positioning or the sense of muscle contraction, and can also be performed passively or actively.

Taking into account the above considerations, it seems logical that the results found in previous studies are certainly contradictory, not allowing valid conclusions to be drawn. This is the case for the study conducted by Bazneshin et al. (2015) who analyzed the effect of local muscle fatigue (quadriceps) on knee proprioception in healthy young people using the joint-repositioning test (targeted knee angle: 45°). These authors reported significant deviations from the targeted angle (increases in absolute and constant error) after administering the fatigue protocol. In this line, Torres et al. (2010) observed how the ability to reproduce two angular positions in the knee (30° and 70°) was diminished for 48 h after applying a local muscle fatigue protocol (multiple eccentric activations of quadriceps until exhaustion). In another study with similar design, Ribeiro, Mota and Oliveira (2007), reported an impairment of knee proprioception of older adults after an effort that induced local muscle fatigue, which resulted in a significant increase in absolute angular error in the joint repositioning test. More recently, Allison, Sell, Benjaminse and Lephart (2016), did not observe any

significant effect of local muscular fatigue on the knee proprioceptive capacity of healthy subjects when the sense of muscle tension associated with this joint was evaluated. For their part, Miura et al. (2004) compared the effects of general and local muscle fatigue on knee proprioception in a group of healthy subjects. The induction of local fatigue, using successive knee flexion and extension movements under maximum isokinetic activation, did not produce significant alterations in joint repositioning capacity after measuring the absolute angular error; however, subjects showed an increase in such error after running for 5 minutes on a treadmill (general fatigue).

Anyway, the investigations carried out with active populations or athletes are smaller in number. Thus, to our knowledge, there are only two studies focused on soccer or soccer players. Carrasco, Nadal and Rodríguez (2005), evaluated a group of semi-professional soccer players after submitting them to a local muscle fatigue protocol finding no effect on knee repositioning performance. Finally, Salgado, Ribeiro, and Oliveira (2015) studied the effects of general muscle fatigue (soccer match) on knee proprioception. After the effort, the semi-professional soccer players evaluated showed a significant reduction in their knee repositioning accuracy.

Considering, on the one hand, that the knee joint and the associated muscles are the most requested anatomical structures in soccer practice, being also those that have the greatest injury incidence, and on the other hand, the controversy existing in the results that have been obtained in previous studies, the objective of the present study was to clarify whether fatigue, either general or local, alters the knee proprioceptive capacity of soccer players.

2 MATERIAL AND METHODS

2.1 PARTICIPANTS

A total of 22 male semi-professional soccer players voluntarily participated in the study. The characteristics of these subjects are summarized in Table 1. They had no injuries at the time of being evaluated and did not show any illness or injury or surgical history that could compromise their participation in the study. Subjects with a history of lower limb injury in the past 6 months were excluded. Participants were informed of the need to avoid physical exercise 48 h before testing sessions. In any case, they signed the consent form after they were fully informed about the characteristics and the aims of the study, whose protocol, adjusted to the provisions of the Declaration of Helsinki of 1964 and later, was examined and approved by the Ethics Committee of the University of Seville.

Table 1. General characteristics of the subjects

	mean (sd)
Age (years)	24 (2,7)
Height (cm)	179 (5,4)
Body mass (kg)	77,1 (12,7)
Body mass index (kg/m ²)	23,8 (3,7)
Experience (years)	15,8 (2,2)
Volumen de entrenamiento al año (h)	261,9 (74,3)

2.2 PROCEDURES

A randomized crossover study design was used. Participants underwent two different fatigue protocols (local and general), and the knee joint proprioceptive capacity was assessed both before and after the application of each protocol. Proprioception evaluation consisted of the active knee repositioning test using the Biodex System 4 Pro isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA), which was calibrated before each session according to the manufacturer's instructions. Taking into account the most frequent injury mechanics, a knee extension movement throughout a joint range of 90° (beginning with the subject in sitting position with the knee flexed 90° and ending with the knee fully extended -0°-) was chosen, while the target angle was established at 30° of flexion. In order to adjust the segments of each subject with the dynamometer input shaft, the lateral femoral condyle of the evaluated leg was made to coincide in height with the rotation axis of the dynamometer, placing the knee attachment clamp 3 cm above the tibial malleolus of the evaluated leg. In addition, the visual information of the subjects was limited with a mask placed over the eyes and the intervention of other body segments or muscle groups was eliminated using the device's restraints and keeping the arms crossed on the chest (Figure 1).

Before fatigue protocols were performed, and with the subject sitting on the dynamometer, the examiner moved the subject's dominant leg until reaching the target angle (30° of flexion), at which time the device was locked to allow the subject maintain the position for 5 s. Once the initial position was recovered, the subject extended his knee again, stopping the movement in the position that, according to his estimation, coincided with the targeted angle. At this moment, the examiner blocked the device again recording the resulting deviation. This process was repeated as many times as necessary until the subject accumulated three consecutive repetitions in which the average of the absolute error was less than 1°.

Based on the proposed research design, and for the purpose of avoiding any effect related to the order of participation and/or the application of fatigue protocol (local or general), the allocation of each tests to be performed by each subject was established using the Randomization program (www.randomization.com). In any case, and regardless of the fatigue protocol assigned to each subject, the first visit to the laboratory served to collect different personal data and other information related to their sports practice. In addition, the participants were subjected to an analysis of their body

composition by means of bioelectrical impedance (TANITA BIOLÓGICA BC-418 MA; Easy Software 8.0.0.980).

The assessment of proprioceptive capacity after fatigue induction was applied just after completing both protocols. With the subject seated on the dynamometer, in the same position as in the pre-fatigue situation, and according to the initial position described above (90° knee flexion), the subject was asked to extend his knee to the target angle. Once the subject considered that he had reached the position, he stopped the action and the dynamometer was blocked to record the angle positioned, repeating this process twice more. The difference between the target angle and the angle positioned by the fatigued subject was considered as the absolute error (without taking into account the direction of the error). On the other hand, relative error, another of the study outcomes, reported the direction of such error (positive if the target angle was exceeded and negative if it was not reached). Likewise, the variable error, defined as the standard deviation of the mean of the relative errors (intrasubject), was assessed. Since these variables were recorded in triplicate, the average value was used in each case.

2.2.1 LOCAL MUSCLE FATIGUE PROTOCOL

The local fatigue protocol consisted of three phases. The first of them consisted of pedalling for 5 minutes on a cycle ergometer (Ergoselect 200) against a resistance of 70 W. Then, with the subject placed on the isokinetic dynamometer as indicated above, the peak torque of the quadriceps of the dominant leg under concentric activation at a speed of 240° / s (knee extension movement; second phase). For this, each subject was asked to perform five maximum repetitions, being the peak torque the maximum value reached in all of them (N / m). After 10 minutes of rest, and once the target knee angle was stabilized, local muscular fatigue (third phase) was induced in the subject's dominant leg. To do this, and from the starting position on the isokinetic dynamometer, the subjects performed successive extension and flexion movements with their dominant leg (240° / s) until the value of the quadriceps torque was less than 50 percent peak value.

2.2.2 GENERAL FATIGUE PROTOCOL

This protocol was performed on a motorized treadmill (H/P COSMOS, 170-190 / 65 / Pulsar). Once the angular repositioning of the knee was stabilized, the subjects performed a continuous running on the treadmill (10 minutes at 10 km / h, 5 minutes at 15 km / h, 5 minutes at 12 km / h, 5 minutes at 15 km / h, 5 minutes at 12 km / h, and so on until exhaustion the subject), constantly monitoring their heart rate with a Polar RCX5 heart rate monitor and recording their subjective perception of effort through the Borg scale (6-20).



Figure 1. Frontal view of the starting position on the isokinetic dynamometer.

A summary of the procedures is shown in Figure 2.

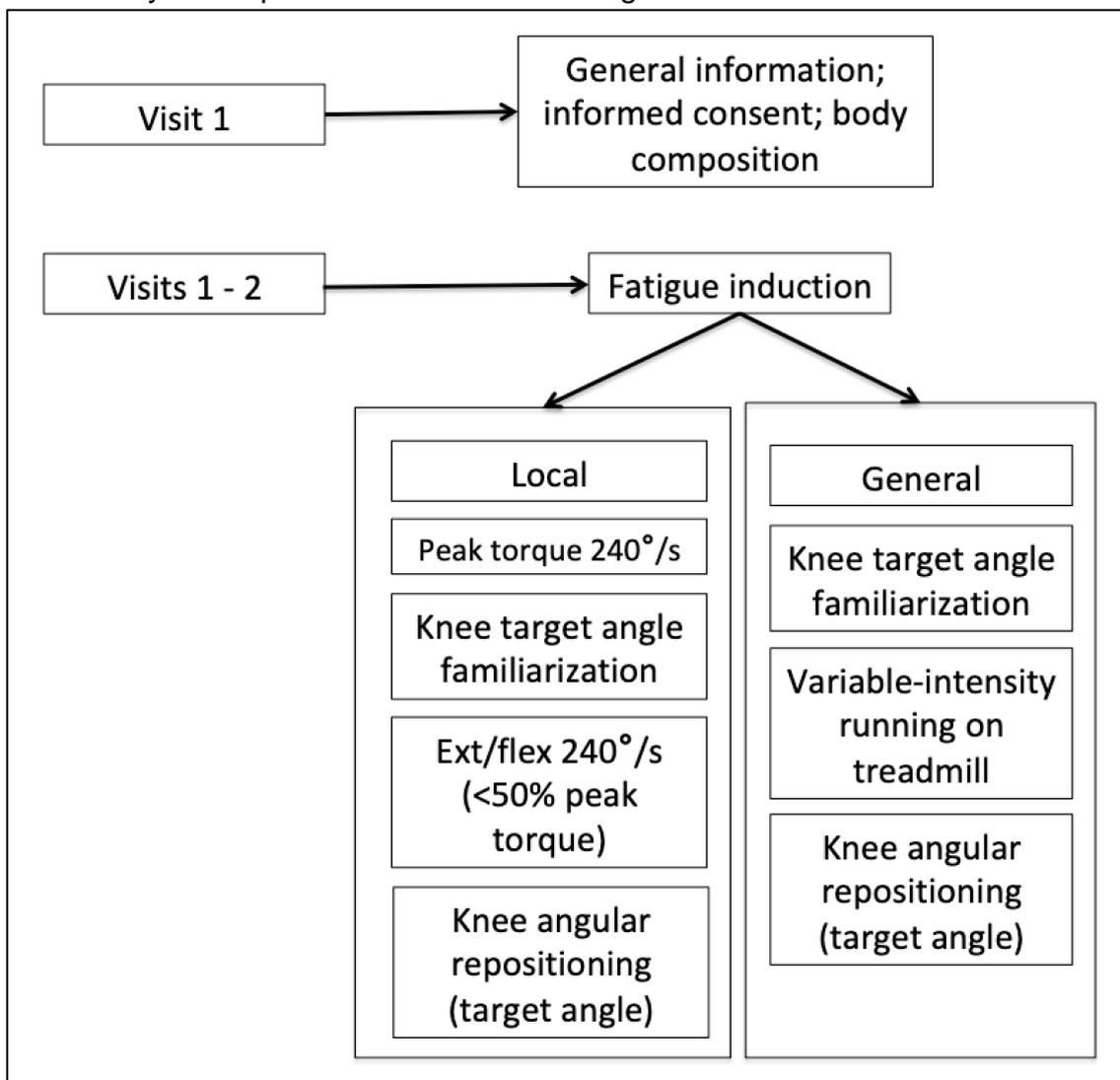


Figure 2. Summary of study procedures.

2.3 STATISTICAL ANALYSIS

The SPSS V.24 (IBM ®) program was used for statistical analysis. All data are expressed as mean \pm standard deviation. The Kolmogorov-Smirnov test was performed on all the variables, verifying that they fit a normal type distribution. Under this premise, one-sample T-test was conducted to check the global effect of both types of fatigue on the joint repositioning accuracy with respect to the target angle (absolute error). On the other hand, two independent samples T-test was carried out to compare the effects of the two types of fatigue (absolute, relative and variable errors); moreover, a repeated measures analysis was performed considering the types of fatigue (local and general) as the main factor and using the relative error obtained in the three post-fatigue evaluations as outcomes. In any case, a 95% confidence interval was established assuming significant differences with values of $p \leq 0.05$.

3 RESULTS

3.1 LOCAL AND GENERAL FATIGUE INDUCTION

Local fatigue was induced by repeated knee extension and flexion actions on the isokinetic dynamometer ($240^\circ / s$) until the torque developed by the subjects in the extension action (quadriceps) fell below 50% of the maximum value previously evaluated ($149.8 \pm 33.4 \text{ N} \cdot \text{m}$). On the other hand, general fatigue was induced using a continuous and variable-intensity running protocol on a treadmill. The subjects carried out this test until their claudication, at which time the proprioception was evaluated. In this way, the following data were collected (mean \pm standard deviation: highest HR achieved in the test: 183.6 ± 19.1 beats per minute; percentage of highest HR achieved in the test regarding the theoretical maximum HR of the subjects: $95.5 \pm 6.9\%$; test duration: 20.1 ± 3.8 minutes; RPE at the end of the test: 19 ± 2.4 points).

3.2 ANGULAR REPLACEMENT OF THE KNEE IN A FATIGUE SITUATION

Table 2 shows absolute error, relative error and variable error data related to the active knee repositioning test in the two fatigue situations considered.

Table 2. Mean absolute, relative and variable errors (degrees) obtained in the active knee repositioning test (target knee angle: 30°) after two fatigue protocols. Sd= standard deviation.

	Local Fatigue			General Fatigue		
	Absolute error	Relative error	Variable error	Absolute error	Relative error	Variable error
Mean	3,1	1,6	2,7	4,4	1,6	1,9
sd	2,3	3,6	1,1	2,3	4,9	1,2

Taking into account the target angle (30°), and regardless of the type of fatigue imposed, the one-sample T test did not show significant differences in the mean relative error ($t = 1,526$, $p = 0.155$ for local fatigue; $t = 1,159$, $p = 0.271$ for general fatigue); on the contrary, in the case of the mean absolute error, these differences were statistically significant ($t = 4,688$, $p = 0.001$ and $t = 6,537$, $p \leq 0.001$, for local and general fatigue, respectively).

Attending to the contrast between local and general fatigue, it appears that both caused similar errors in knee repositioning accuracy, since there were no significant differences in the absolute error ($t = -1,340$, $p = 0.194$), relative error ($t = -0.014$, $p = 0.989$), and variable error ($t = 1.778$, $p = 0.90$). Furthermore, the absence of differences in this last error suggests that the variability observed in the responses of the subjects was independent of the two situations to which they were exposed (local and general fatigue).

In line with the above, other interesting results indicate that both types of fatigue not only caused similar relative errors but also in the same direction. Considering the target angle fixed at the knee (30° of flexion), the starting position (90° degrees of flexion), and that the subjects tried to place their knees at the target angle through a voluntary movement of knee extension, the positive value of the mean relative errors suggests that this angle was exceeded approaching to the full extension of their knees.

Lastly, and although the type of fatigue could determine the effect of time and/or the number of evaluations performed after exertion (absolute and relative errors tended to decrease after induction local fatigue while they were maintained or increased with general fatigue), no significant differences were observed (Figure 3).

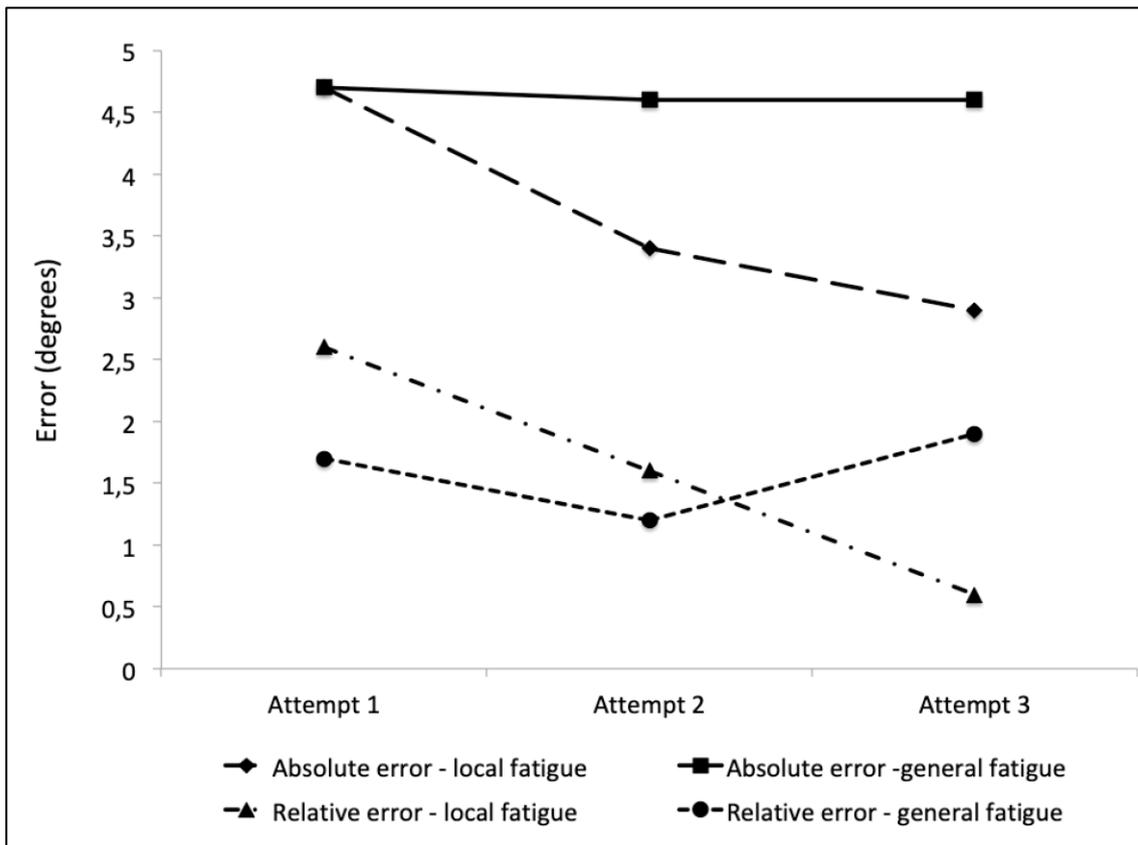


Figure 3. Mean absolute and relative errors in the active knee repositioning test.

4 DISCUSSION

The main objective of this study was to verify if exercise-related fatigue can affect the knee proprioceptive capacity in soccer players, differentiating, at the same time, what type of fatigue (local or general) could cause a greater disturbance.

The proprioceptive capacity in the soccer players participating in this study was assessed by using the active knee repositioning test (open kinetic chain) on a target angle (30° of flexion) that was previously determined in the dominant leg of these subjects (Ribeiro et al., 2007). The usefulness of this test is based on its reliability, which has been previously established by Salgado et al. (2015) using the same variables as in the present study (average relative error, average absolute error and variable error).

The results obtained in our study show how fatigue, regardless of its typology, affects the knee repositioning accuracy in the soccer players evaluated. However, it is important to consider that this effect has only been observed for the mean absolute error, not appreciating such effect when considering the mean relative error. This circumstance is of great importance since the results obtained could be diametrically opposite depending on the type of error considered as the main outcome. As in the present study, recent investigations focused on joint repositioning evaluation reported measures of both types of error (Bazneshin et al., 2015; Salgado et al., 2015). In line with these studies, the mean absolute error obtained in our study was higher than the mean relative error, although the latter showed a greater dispersion due to its bi-directionality.

Anyway, it does not seem that local or general fatigue affects to a greater extent the proprioceptive capacity of these subjects since, regardless of the type of error used to

contrast, no significant differences were observed after comparing the effects of the two types of fatigue. Thus, our results are partially in line with those reported by Torres et al. (2010), who found a lack of accuracy in a knee repositioning task after the induction of local muscular fatigue (repeated eccentric actions of the quadriceps until exhaustion). Furthermore, it should be noted that this effect remained for up to 48 h after fatiguing exercise. This proprioceptive alteration was also observed by Ribeiro et al., (2007) who found an increase of mean absolute error in a knee repositioning test after exercise-induced local muscle fatigue.

However, our results slightly differ from those provided by Miura et al., (2004), who found no effect of local muscle fatigue (quadriceps) on knee proprioception but that, on the other hand, was affected by general fatigue (induced by 5 minutes of intense running on a treadmill). The lack of objective criteria to define the state of fatigue as well as the selection of a random target angle between 10 and 80° make the comparison difficult. In the latter case, the establishment of certain target angles (near the limits of this interval) implies that the proprioceptive information generated by ligaments play a key role in an active joint repositioning task, being able to compensate, in a certain way, for muscle fatigue that could directly affect other muscle areas (i.e. contractile fibers). Apart from this, Carrasco et al. (2005) found no significant differences when the angular deviation caused by local muscle fatigue (quadriceps) in knee repositioning test was compared with that previously recorded in baseline conditions. Moreover, similar results were reported by Allison et al. (2016), who analyzed the effect of local muscle fatigue on knee proprioceptive capacity using both the joint repositioning test and the sense of tension of knee-related muscles.

The effects of local muscle fatigue on proprioception appear to target muscle spindles. According to Torres et al. (2010), intrafusal fibers generate a disturbing afferent signal that compromises the subsequent repositioning at the target angle. Furthermore, according to these authors, the mechanoreceptors located in the tendon (Golgi organ) could also modify their afferent signal in the same way, causing erroneous proprioceptive information processing. In this line, Forestier, Teasdale and Nougier (2002), established that local muscular fatigue activates pain receptors by increasing metabolites concentration which also affects the discharge pattern of the muscle spindles, resulting in an increase in their excitatory threshold that leads to a reduction in the afferent signal (Sogaard, Gandevia, Todd, Petersen and Taylor, 2006). In fact, it has been pointed out that the lack of accuracy in joint repositioning under acute muscle fatigue could be caused by both the reduction of sensitivity and the disrupted signal emitted by groups III and IV afferent fibers (Yaggie and Armstrong, 2004).

On the other hand, and regarding the effects of general fatigue, our results, expressed by the mean absolute error, are in line with those reported by other previous investigations. One of them is the study conducted by Miura et al. (2004) who reported a decrease in joint repositioning accuracy after an intense running on a treadmill. Nevertheless, Salgado et al. (2005) evaluated the proprioceptive capacity on the knee joint in soccer players after a soccer match. Considering that soccer player experienced mainly general fatigue, both absolute and relative errors increased significantly in the knee repositioning test. Furthermore, in our study, general fatigue protocol induced a proprioceptive alteration which could only be measured in terms of absolute error (Figure 3). This lack of accuracy in the knee repositioning task under general fatigue condition was maintained throughout the three evaluations performed by the subjects participating in the study. Under this consideration, it could be speculated that general fatigue could affect proprioceptive capacity more than local fatigue. However, several limitations such as differences in the protocol used to induce general fatigue (intensity, duration, type of exercise ...) as well as the use (or not) of valid criteria to verify the level of fatigue achieved could compromise this statement making difficult the comparison between investigations. In this sense, and unlike previous studies, a variable-intensity running test (until exhaustion) was applied in this

study; furthermore, the level of fatigue could be verified by the HR achieved in the test (95% of the theoretical maximum HR) and the mean score of 19 points on the Borg RPE scale (6 to 20 points). Although this protocol, with a mean duration of 20 minutes, is shorter and less specific than that proposed by Salgado et al. (2015), it allowed us to evaluate the subjects under the same fatigue conditions, which is difficult to achieve in soccer matches, where players perform different roles and, consequently, they are not fatigued to the same extent. In any case, and in addition to the local fatigue effects, general fatigue can affect other mechanisms in the processing of proprioceptive information at the central nervous system rather than interfere with the afferent signal from muscle spindles. In this sense, exertional exercises, such as what was used in this study, induce central fatigue, which, in turn, reduces motor control precision and movement efficiency, and could compromise knee-joint stability (Miura et al., 2004; Salgado et al., 2015). Thus, Hiemstra, Lo and Fowler (2001) established that the decrease observed in proprioceptive capacity after induction of general fatigue (i.e., strenuous exercises that involve a lot of muscles at once) may be due to an impairment in the processing of proprioceptive information, that is, the so-called central fatigue. However, according to Allen, Leung and Proske (2010), the effects associated with local (peripheral) muscle fatigue can also exert their influence on proprioception at the central level; however, in this case, it is difficult to clarify what factors may have a greater influence affecting the joint repositioning sense (Abd-Elfattah, Abdelazeimb and Elshennawy, 2015; Salgado et al. 2015).

Regarding the direction of deviation in the knee repositioning test (expressed by the mean relative error), and regardless of the type of fatigue induced, the results of our work differ from those found in most previous studies. In these investigations, negative values were recorded for mean relative error, which translates into positions closer to full knee flexion (after fatigue induction, subjects extended their knees but they did not reach the target angle; Allen et al., 2010; Givoni, Pham, Allen, Proske, Salgado et al., 2015). Some of these authors point to the fact that local muscle fatigue (knee-flexors muscles) plays a decisive role in the direction of mean relative error; however, Givoni et al. (2015), who exclusively fatigued the knee-extensor muscles, also found negative mean relative errors, which suggests that the direction of this error could be independent not only of the type of fatigue but also of the muscle group to be fatigued.

Finally, some limitations should be considered. First, the quadriceps peak torque was only recorded before the local muscle fatigue protocol to identify the local fatigue status (drop below 50%). Although different physiological indicators were assessed to certify the presence of general fatigue, it would have been interesting to measure the peak torque of involved knee before this exercise protocol, thus allowing us an alternative contrast between the two types of fatigue induced. On the other hand, and as it has been proposed in previous studies, the joint repositioning was evaluated through an extension movement of the knee which focuses attention on the effects of fatigue on the quadriceps muscle and the mechanoreceptors distributed among its fibers; however, an interference with these receptors in the knee flexor muscles could be expected, especially when they were elongated along with the leg extension movement to reach the target angle. Moreover, hamstring muscles were also subjected to local and general fatigue, and their effects could be summative to those generated on the quadriceps. Lastly, by evaluating subjects twice consecutively according to the same target angle, the occurrence of a progressive (learning) error could be questioned. Nevertheless, the use of an individual random order for each protocol, absence of feedback about performance as well as the stability of the mean absolute error in general fatigue conditions, do not support this possibility.

5 CONCLUSIONS

This study offers several conclusions. Firstly, the effects of fatigue on knee proprioceptive capacity of soccer players should only be evaluated using the mean absolute error, questioning conclusions reached from measures of mean relative error. Under this perspective, both types of fatigue altered the knee proprioceptive capacity of these athletes, although the alteration caused by general fatigue seems to be more stable. Taking into account all these circumstances, the evaluation as well as the specific proprioceptive training acquires special relevance from a preventive point of view by allowing greater stability in key joints for this type of population.

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