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Fatigue: The consequences of a tennis match, determined by 20 Hz GPS

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Abstract
The purpose of this study was to analyze the variations in technical-tactical and physical abilities as a result of the fatigue caused by a tennis match. The study was performed on two second-class tennis players (ITA), with a pre-post test protocol. The game was played under the ITF (International Tennis Federation) rules; for a defined total duration of 1 h and 30 min. The pre-post analysis covered the following capabilities: explosive strenght (EF) by Sergeant test, speed (V) was tested by the change of direction test, static equilibrium (SE) was evaluated with the stork test, the accuracy of the strokes (AC) was examined through the Loughborough Tennis Skill East: groundstrokes and finally the joint mobility (JM) was observed with the sit and reach test. The speed test was carried out using 20 Hz GPS (K-Sport Universal, Italy). The use of this instrument in tennis is still very rare; in scientific literature there are few published studies, as opposed to football, and other sports, where there are a considerable number of papers. The use of the GPS and the dedicated K-Fitness software (K-Sport Universal, ITA) allowed an accurate and objective analysis of performance elements, which we consider to be an initial step forward on qualification and quantification on performance parameters in Tennis.

Keywords: GPS, fatigue, tennis performance, performance analysis

Introduction
The onset of fatigue and is quantification has always been a main goal for sports analysts. The performance of athletes during matches or workouts is greatly influenced by time and intensity of work.

In Tennis the duration of matches can range from 1 hour and 30 minutes to 3-4 hours, is definitely among the sports where qualifies the resistance as an indispensable element for the quality of the game itself. The study of fatigue in tennis is a topic that has been dealt several times, analyzed on single game or simulating a tournament. (Hornery, Farrow, Mujika, & Young, 2007) [7]. In our study we used the Sergeant test to analyze the explosive strength (ES), Loughborough's Tennis Skill Test: Groundstrokes to study the accuracy of the strike, Change of direction test to examine the speed, Sit and reach test to control the flexibility and Stork Test to observe the balance. The speed was analyzed using a 20 Hz GPS (K-Sport Universal, ITA) which allowed to examine the distance at high speed (DHV> 16km / h), the high acceleration distance ACCHI > 2 m/s2 and the high deceleration distance DECHI <2 m/s2. The aforementioned data have already been studied in other sports (Izzo & Carrozzo, Analysis of significance of physical parameters in football through GPS detection in a comparison with amateur athlete, 2015, Izzo & Lo Castro, Izzo & Morello, Izzo & Sopranzetti, Speed, acceleration, deceleration and metabolic power in the work to roles for a workout more targeted in elite football, 2016) [12]. The study of fatigue has already been treated several times in tennis; Davey *et al.* (2002) [3] examined 18 adult players (9 males and 9 females) before submitting them to the Loughborough Tennis Skills Test for the baseline shots and for the service, then the Loughborough Intermittent Tennis Test took place, in order to induce fatigue, also monitoring the heart rate, body mass and glucose and lactate peaks in the blood, and then repeat the first two tests. the results obtained from the protocol did not signal any differentiation between the first detection for background shots and the second, while for the service there was a decrease in accuracy by serving from the right, in the intermittent tennis test a decrease in Accuracy advancing in the test path (Davey, Thorpe, & Williams, 2002) [3].

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Girard *et al*. (2006) [6] examined the maximal voluntary contraction in the execution of a voluntary maximum isometric contraction of the right knee extender and the explosive force with an isometric ergometer before, during (every 30 min) and after a tennis match lasting 3 h, in 12 adult players. The results reported by this study are a decrease of the voluntary maximum isometric contraction, the peak of power in both tests does not show decreases during the match, but only in the last test, carried out 30 minutes after the end of the match, the evaluation of the effort perceived and muscle soreness of the knee extensor increased linearly during the course of the match by demonstrating a connection between them, a link between the actual playing time and the heart rate was also noted. Gescheit Danielle T *et al*. (2015) have developed a protocol according to which they proceeded by carrying out 4 games of one hour each on consecutive days, trying to analyze the effect of several meetings, in 7 well-trained players. The results showed a decrease in voluntary maximal isometric contraction, perceived muscle soreness and blood tests found an increase in soreness and CK in the blood, the Multi-Component Training Distress Scale found an increase in the humoral evaluation, the external load has seen a drop, while the internal load has remained almost unchanged between the different days regarding the assessment of the perceived effort, and a drop in the heart rate.

Objective
The aim of this study was to check the fatigue after 1 hour and 30 minutes of a tennis match, on two 2th category players (ITA) with a Pre-Post Test method, sample was composed of two players:

Table 1: Player data

	Athlete 1	Athlete 2
Category	2.7	2.5
Age	24	27
Height	181 cm	180 cm
Weight	70 Kg	72 Kg

Means and Methods
Before starting the players played a 10 minute warm-up, divided into 5 minutes of run and 5 minutes of free sparring passages, then the test protocol was followed:
- Loughborough's Tennis Skill Test: Groundstrokes (Lyons, Al-Nakeeb, Hankey, & Nevill, 2013) [14]
- Change of direction test, (Girard, Christian, Racinais, & Périard, 2014) [5]
- Sergeant's Test, (Buonaccorsi, Forza rapida, 2017) [1]
- Sit and reach test, (Buonaccorsi, Mobilità articolare, 2017) [2]
- Stork Test (Johnson & J.K., 1979) [13]

During Change of direction test a 20 Hz GPS (K-Sport Universal, ITA) was used to monitor the distance trayveled at high speed (D_SHI) >16 Km/h, distance travveled at hig acceleration a > 2 m/s/s (ACCHI) and the distance travveled at high decelleration a < 2 m/s/s (DECHI). After the pre-test, was played a normal tennis match lasted for 1 h 30 minutes, respecting the rules of the International Tennis Federation (ITF), which consist of intervals between one point and another of maximum duration of 20s, while during the field changes made after every odd game, the time interval was not superior at 1 minute and 30 seconds, except in the first game of the set where the field change was made without being able

to sit on theyr bench. On any 40-point score was followed the rule of advantage and the set ends when one of the two players arrives at 6 won games with the other who has reached maximum 4 games, otherwise a 7 game set extension will be applied, in the case of 6 equal tie-breaks, if the match ends before 1h and 30 minutes, another set will continue until the time expetect will reached, without evaluating the result. At the end of the game, was performed the post-test protocol.

Data analysis
The following tables shows data from players, A1 in the two columns on the right, A2 in the two columns on the left, before and after the game.
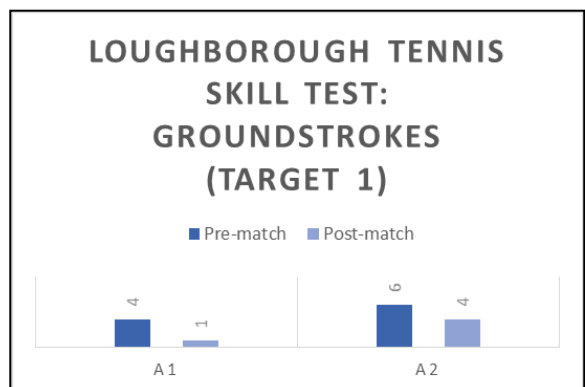Using the GPS it was possible to detect the following data:
- High acceleration distance: D_AccHI (> 2 m / s / s)
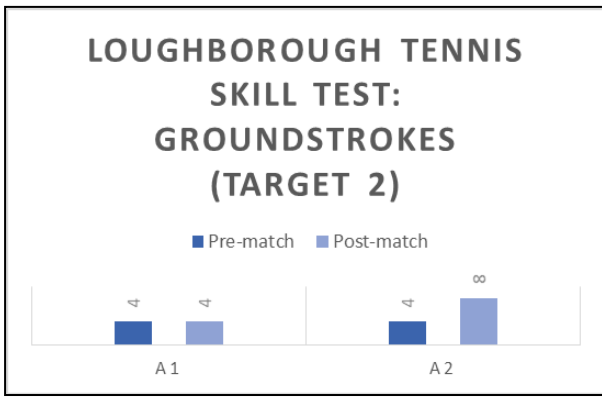- High deceleration distance: D_DecHI (<2m / s / s)
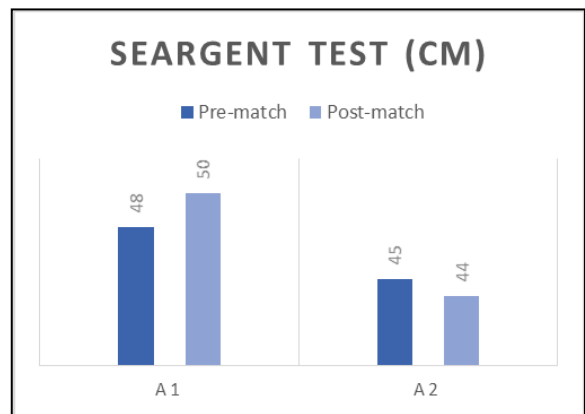
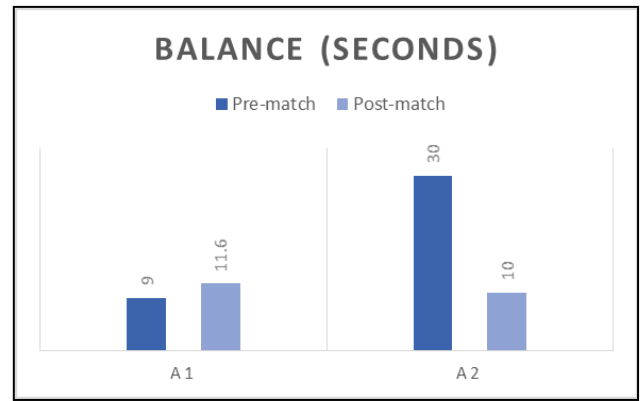**Fig 1:** Data from Sergeant's test, for both players, measured in pre and post-match
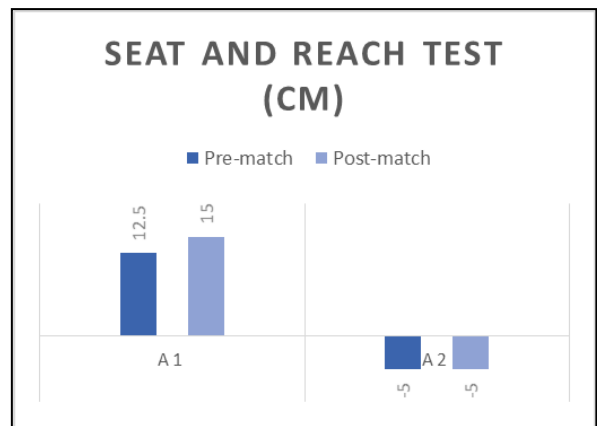
Fig 2: Data from Seat and Reach Test, for both players, measured in pre and post-match
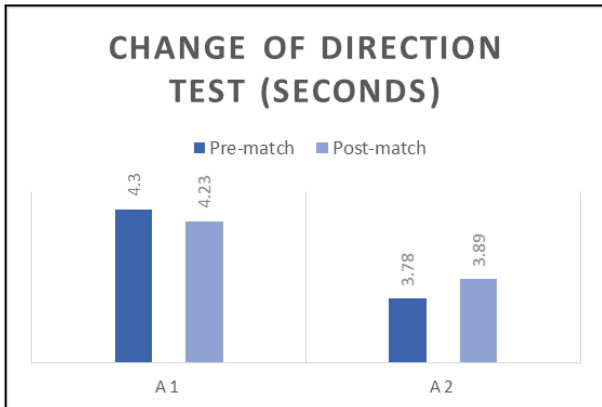

Fig 3: Data from Loughborough tennis skill test: groundstrokes (target 1), for both players, measured in pre and post-match
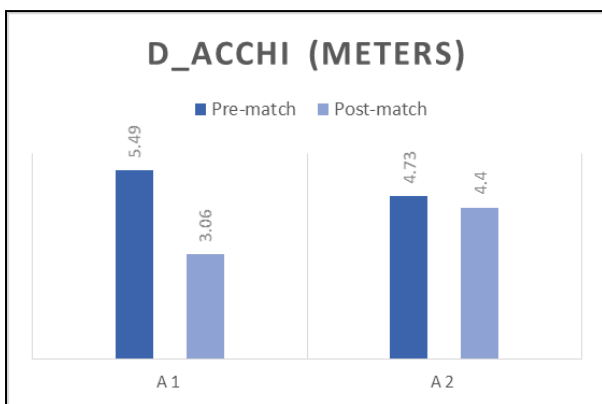
Fig 4: Data from Loughborough tennis skill test: groundstrokes (target 2), for both players, measured in pre and post-match
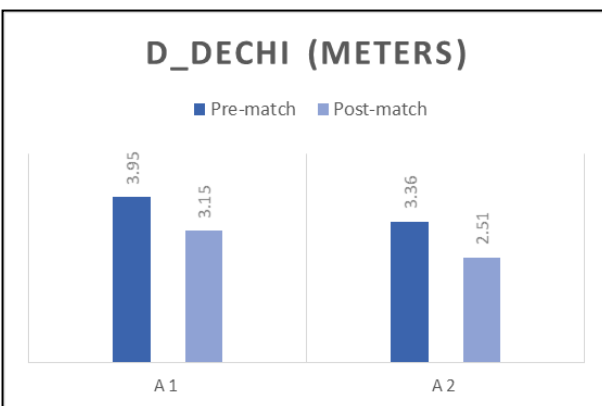

Fig 5: Data from Change of direction test (seconds), for both players, measured in pre and post match

Fig 6: Data from Change of direction test (high acceleration distance), for both players, measured in pre and post match

Fig 6: Data from Change of direction test (high deceleration distance), for both players, measured in pre and post-match

Fig 7: Data from Stork Test (seconds), for both players, measured in pre and post match

Discussion

Fatigue may result in a decrease in physical and technical performance; the objective of this study is to observe the changes in the performance of two players, second category (FIT), before and after a match of 1 h and 30 min; through the use of GPS. From the collected data it can be observed that, in the pre-match test for explosive strenght A1 obtained a result of 48 cm in the jump, while, in the post-match he reached 50 cm, with a 4.17% improvement; while A2 reach 45cm in the pre-match, and 44 cm in the post-match; showing a decrease of -2.22% (Fig 1). In the detection of flexibility, A1 had a result of 12.5 cm in the pre-match test, while 15 cm in post-match it reached, achieving a 20% increase; while A2 in both tests has reached -5 cm, showing neither an improvement nor a worsening (Fig 2). In the test for the accuracy of the shots, A1 obtained a result of 4 in the pre-match test, and 1 in the post-match, highlighting a decrease of -75% targeting the target 1, while it remained unchanged for target 2, obtaining a score of 4 in both tests; A2 obtained, on target 1, a score of 6 in the pre-match test, and 4 in the post-match, pointing out a decrease of -33.33% and a 100% increase for target 2, obtaining 4 in the pre-match test and 8 in post-match (Fig.3-4). Time for A1 to complete the change of direction test was 4,3 s in the pre-match test, while in the post match, the distance was traveled in 4.23 s, obtaining an increase of 1.63%; while, the tests carried A2, reached a time of 3.78 s in the pre-match test and 3.89 s in the post-match, showing a decrease of -2.91% (Fig 5). The D_AccHI traveled, for A1 was 5.49 m in the pre-match, and 3.06 m in the post-match, revealing a decrease of -44.26%; for A2 was 4.73 m in the pre-match and 2.83 m in the post-match, decreasing by -40.17% (Fig 6). The D_DecHI traveled, from the athlete A1, in the pre-match was 3.95 m, ad 3,15 m in the post-match, exposing a decrease of -20.25%, while for A2 was 3,36 m in pre-match and 2,51 in post-match, with a decreasing of -25.30% (Fig 7). In Sotk test, A1 obtained a result of 9 s in the pre-match and 11.6 s in the post-match, showing an increase of 28.89%, while A2 shows a performance of 30 s in the pre-match and 10 s in the post-match, with a decrease of -66.67% (Fig 9). To be highlighted are the data collected through the GPS that allowed the detection of the D_AccHI and D_DecHI otherwise not detectable without its use. Comparing the acceleration we can see how in the pre and post-match test, the athlete A1, get higher results, despite a greater drop in performance between the pre and post-match. In deceleration, the A1 athlete has traveled a greater distance, in the pre and post-game than the A2 player, also making a minor decrease in performance. Given the low number of athletes participating in the protocol, more reliable data could be obtained by

examining a larger sample of players in the same levle, or higher.

Conclusion

The objective of this study was to observe if tennis performance can be negatively or positively influenced by a 1 hour and 30 minutes of game while introducing GPS (20Hz) to detect data of distance traveled on acceleration, deceleration, and high-speed distance. In our view, those parameters can be crucial to propose and differentiate better workouts programme based on real matchs data. From the results obtained it can be deduced that, after 1 hour and 30 minutes of game, the two athletes have not yet developed a fatigue that leads to a significant decrease for all tested capability and abilities, indeed, it has also been possible to observe an increase of several of them. The protocol can be improved by considering more athletes, maintaining the same level of gameplay, or involving more advanced technically and differently qualified players of different ages. The Sergeant test, proposed to detect explosive strenght, can be made more accurate using a Bosco or ergojump platform; to monitor the speed, the stopwatch can be enriched by photocells, allowing accurate and accurate detection. The idea was to conduct a pilot study in tennis by testing the possibilities of detecting objective data, using GPS, other futher studies are needed to investigate fatigue in tennis.

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