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The study of acceleration and deceleration capacity decrease in repeated sprints in soccer

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Abstract
The Updated studies published show that among most important capacities in soccer performance are acceleration and deceleration. Hence, these two capacities determine an athlete's efficiency in many match components such as dribbling, "1 vs. 1", etc.
The purpose of this study was to analyse acceleration and deceleration capacity through innovative technology such as GPS receivers, able to analyse this capacity during a whole exercise session, and to give researchers the possibility to study the trend through the use of a software (Prozone Kinetics, ProZone®).
Ecarried out by the Urbino University Carlo Bo/School of Health and Sport Science and K-Sport Research Group, led by Riccaro Izzo and Mirko Marcolini, the research aimed at studying the correlation between fatigue and the ability to accelerate and decelerate.
In the bibliography, the most used test to evaluate acceleration and deceleration capacity was the "Capanna Test". GPS receivers were used to analyse this test and the result found was not satisfactory as the decrease trend was not clear enough to be able to detect the effects of fatigue.
The test parameters were then modified to find the best way to reach the aim of the research. The final test was 6 repetitions of 5mt (5+5+5+5+5+5mt) interspersed with 20 seconds passive recovery; after each 5mt the athletes were required to break suddenly.
In conclusion, the research showed that this test is an efficient means of analysis of acceleration ability but it needs further development as far as deceleration is concerned. Furthermore, this study showed that GPS technology is to date one of the most accurate methods in acceleration and deceleration studies.

Keywords: Performance Analysis, GPS, Soccer performance, Acceleration, Deceleration.

Introduction
A detailed investigation of all the studies related to team sports, and particularly situational sports like soccer, have shown that the most frequent action in soccer matches is the capacity to accelerate and decelerate.
It is believed that the different acceleration and deceleration capacity in athletes determines the overall quality of each player, their capacity to dribble, win a 1 vs 1, and score goals.
This study carried out by the Research Group in Performances Analysis of Urbino University, Carlo Bo' School for Health and Sport Sciences and K-Sport, led by Riccardo Izzo and Mirko Marcolini, will therefore investigate acceleration and deceleration, fundamental performance parameters, with the use of the latest GPS technology (K-Gps 10Hz, K-Sport, Montelabate, PU, Italy).
These devices can monitor and assess acceleration and deceleration during the whole activity thus providing a much more accurate analysis based not only on running speeds measured using photocell timing gates.
The present study has attempted to investigate the effects of fatigue on acceleration and deceleration capacity.
A state-of-the-art approach has been the basis of the current study. As a starting point for the investigation, the Capanna test (6 sets of 20 mt return sprints with 20 seconds of rest in between) has been chosen amongst a range of available tests, as it is accepted by the entire scientific community as the most thorough and valid to assess sprinting capacity.
The aim of the study was to investigate and demonstrate the validity of the test through the use of GPS devices, and to show and corroborate that there is a decrease in acceleration and deceleration curves, which can subsequently help to identify elite and sub-elite performances or, simply, to provide an athlete eventually new, quanti-qualitative profile.

State-of-the-art

Since now it has not been possible to find any publications related to the current research because the study of acceleration and deceleration curves has been carried out through the introduction of GPS devices, to date used by only few researchers.

What have thus been analysed are those studies that would set a starting point for this research, particularly those related to fatigue in repeated sprints.

What appears in the current literature on studies related to repeated sprints focuses mainly on Repeated Sprint Ability (referred to as RSA).

RSA is the capacity of sprint repeating over a period of time. During their whole training session (1-4 hours), team sport athletes undergo repeated maximal efforts (sprints) interspersed with brief recovery bouts, which can be either passive (complete or partial rest) or active (low intensity activities, e.g. a walk).

In his study done in 2007, Rampanini corroborated a significant correlation (r) between RSA, particularly connected with a decrease in peak speed, and:

- distance covered (r=.58);
- high intensity running (r=.65)
- Very high intensity running during competitive games (r=.64) for example, soccer matches.

The capacity of repeated sprints clearly decreases with prolonged performance. Specifically, accumulated fatigue (e) will negatively affect RSA. Fatigue, therefore, influences performance by acting on a wide variety of factors both on a neural level, like an inadequate brain cortex motor command (motor area), and on a muscle level, with muscle metabolite accumulation. However, what needs to be stated is that none of these factors work alone, and fatigue is the result of a number of limiting factors.

Despite what has been mentioned above, a clear explanation of the main factors limiting RSA has yet not been found. On a physiological level there is a correlation between fatigue from RSA and both phosphocreatine resynthesis (PCr) and hydrogen ion muscle release during recovery.

A good performance is hence closely connected to the level of fatigue. Many sport event performances, as the ability to win ball possession and not concede goals, are, in fact, influenced by the capacity to perform high intensity sprints, which help distinguish top class players from players of a lower standard. Athletes who are able to repeat sprints at the same or very similar intensity and quality are therefore likely to perform better over extended periods of time. In their 2004 study, Spencer and Lawrence reported that there is a high concentration of repeated sprints in soccer matches, especially just before scoring or taking a goal, thus reinforcing the correlation between the capacity of repeated sprints (RSA) and the match outcome. What needs to be also taken into account in the analysis is that sport performance can depend on physical, technical, tactical and mental factors.

In 2011 Girard, Mendez-Villanueva and Bishop conducted a study which aimed at analysing those factors contributing to fatigue in RSA, and they reported that fatigue in sprinting was associated with speed decrease. However, the study was not been able to clarify what the real performance limiting factors were, leaving space for further research.

The study examined how fatigue manifested during "Repeated Sprint Exercise (RSE), which were a series of sprints (≤10 seconds), separated by short (≤60 seconds) recovery periods. This type of exercise showed a decrease in level performance from early sprint exercises, unlike intermittent sprint exercises consisting of short sprints interspersed with longer recovery intervals (60-300 seconds), which allow for a full physiological recovery of sprinting capacity.

Regarding the correlation between RSA and VO_{2MAX} (maximal oxygen consumption), to date, only a limited number of studies have examined the relationship between VO2max and RSA with one study reporting a significant relationship betweenVO2 max and total sprint time (RSA total; r=0.49) in a group of amateur team sport athletes. In 2013 Jones conducted an innovative study on the relationship between RSA and VO_{2MAX} using a specific RSA protocol in professional soccer players, and found a relationship between RSA and VO_{2MAX}.

Studies based on *Match Analysis* investigated player performance during matches in order to observe when fatigue was mainly manifested. Undoubtedly, these studies have shown that both adult and young soccer players cover less running distance in the second half of the match than in the first. Furthermore, elite adult players have been reported to cover 43% less distance sprinting in the final 15 minutes of a match than in the first 15 minutes.

However, it must be said that the studies carried out through *Match Analysis* can give an irregular pattern influenced by tactical factors, which can affect performance factors. The following standardized protocols monitor athlete response to specific soccer exercises. One of the most reliable laboratory instruments and methods for measuring soccer-specific exercises, which allow the athlete to accelerate, decelerate and sprint as for free running, is the non-motorised treadmill (NMT).

The study of repeated sprint ability has progressed at the same rate as the creation and validation of repeated sprint ability tests.

Soccer-specific field tests are the most popular due to their simplicity and minimal use of equipment. Nevertheless, some of these tests have been, in retrospect, criticized for not reflecting neither individual variation nor the most demanding physical stages of a match; a test on RSA should replicate high intensity activity during a match rather than an average intensity.

A very popular field test is the "Yo-Yo Intermittent Endurance Test" (YYIET) which is a progressive 20m shuttle run test with a 5 second recovery. J. Bangsbo's protocol is slightly different as it consists of repeated exercise bouts performed at progressively increasing speeds, interspersed with 10s active recovery periods, and performed until the athlete is exhausted.

There are two versions of each Yo-Yo Intermittent Test:

- Level 1: the exercise is performed at progressive speeds
- Level 2: the exercise time can vary from 5 to 15 minutes

The "Yo-Yo Test" shows an increase in heart rate and oxygen uptake; it is also possible to observe muscle metabolism through muscle biopsies and blood tests. Thanks to the latter analysis, where it is possible to observe blood lactate and creatine phosphate levels, it can be confirmed that in team sport performances, particularly in situational sports (soccer, rugby and basketball), anaerobic muscle metabolism is involved. As it correlates with heart rate, the test is believed to be one of the most accurate for measuring and evaluating maximum heart rate reached by an athlete while undergoing the test, which will also be able to evaluate the athletes in different stages of the season.

Conversely, until now Yo-Yo tests have shown to be a less sensitive and valid measure of change, and their reproducibility less attained, when the correlation is between the test itself and high level physical sport performances where high and low intensity phases alternate.

The most common recent test has been the “20mt Shuttle Run Test” (20mtSRT), also known as the “Léger test”. It was described for the first time in 1984 by its creator Luc Leger, who aimed at developing a test which could assess both athletes’ overall aerobic abilities and repeated sprint ability.

The original version of the test described a protocol of 20m sprints interspersed with a one minute recovery period. The test is divided in subsequent levels with running speed differences, which are synchronized with recorded beeps at set intervals.

Over the years a number of studies have confirmed the test validity and accuracy to estimate both maximal oxygen consumption ((VO_{2Max}), or maximal aerobic capacity, and repeated sprint ability, or RSA, of athletes undergoing the test.

The “20mtSRT” test has a number of variants, which have been elaborated even by Leger himself. There are three distinct 20-mSRT protocols in use:

- The original Lèger protocol which starts at a speed of 8.5 km/h, and increases in speed by 0.5 km/h each minute.
- Eurofit protocol which starts at a speed of 8.0 km/h, the second stage is at 9.0 and thereafter increases in speed by 0.5 km/h each minute.
- The Queen’s University of Belfast protocol which starts at 8.0 km/h, and increases in speed by 0.5 km/h each minute.

Nowadays, the most used variant is the Eurofit protocol as it is believed to be the most accurate.

A number of other tests have developed from the Lèger test. One of these is the “Capanna test”, which was elaborated at the end of the 1980s by Riccardo Capanna and made public by Roberto Sassi. This test aims at assessing a person’s body capacity in performing several sprints at maximum speed with minimum recovery. The test consists of 6 sets of 20mt complete sprints with a recovery of 20 seconds between sprints.

The validity of the “Capanna test” was first assessed in a 2007 study by Impellizzeri, who, by using *Video Match Analysis*, believed to be the most complete and valid tool for assessment, compared test data with match data and found a correlation in high intensity stages.

Another very popular test to evaluate RSA is the “Montreal University Track Test”. Athletes need to complete a 50mt run at increased speeds indicated by an audio signal at the beginning and end of the sprint. The test is ceased when the athlete falls meters short of the designated marker, or when the subject feels they cannot continue the stage. Though the test is definitely economical and repeatable, it has not been corroborated by further studies and therefore has little scientific validity.

Among other tests there is the “5x30mt” and the “10-8-8-10”. The first aims at evaluating efficiency in performing maximal sprints with reduced recovery time: 5 maximal 30mt sprints and a 30 second rest time between sprints.

The “10-8-8-10” test evaluates change of direction ability. Besides assessing athletes’ physical abilities, the test evaluates another important performance component, which is agility.

Another test to assess repeated sprint ability is the “Carminati test”, developed in Coverciano research centre (Italy) which requires athletes to increase both speed and distance at every stage of the exercise.

Another basis for the current research has been to be able to identify high-intensity effort during a soccer match. For this reason the study has attempted to indicate a soccer performance model by analysing all the research done so far.

Soccer is the world’s most popular sport, and it is practised by men, women and children. As for many other sports, science can help improve soccer performance. For this reason, many studies have been done over the years, which have attempted to define, in the best possible way, a performance model able to give a detailed description of all the physical activity carried out in a soccer match.

The first analytical and scientific studies on team sports, and on soccer, were carried out in the 1980s. These studies were the first to report that most team sports consist of a running activity with variations on speed and direction.

To date, the studies have shown that the motor components of a soccer performance are:

- Sprinting
- Jumping
- Recovery
- Direction change
- Different high-intensity running
- Endurance
- High speed personal qualities

As regards different high-intensity running, a recent study by Colli *et al.* helps to define high-intensity. The research has shown that there is a considerable difference in distance covered at various speeds, and that performance variables are influenced by the type of competition as well as the importance players attribute to the competition itself. The study analysed the matches of a top soccer team in 3 different competitions: the National League, the European Cup and the National Cup, through a system of match video analysis called “Amisco”. The match analysis showed that in the less prestigious competition, the National Cup, the players had performed more high-intensity running.

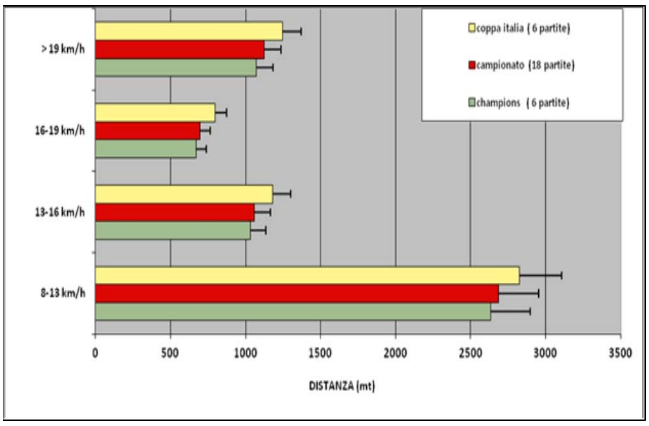

Fig 1: Distance covered by a forward player in three different competitions. (Colli, *et al.* s.d.).

Figure n. 1 shows the distance covered by forward players at various running speeds. A mere analysis of the above chart would conclude that the players were fitter in the less prestigious competitions rather than in the top level ones; this type of analysis is not accurate. The reason why in less prestigious competitions, like the National Cup, the tested players cover more distance at high-speed is not an indicator of best physical condition; rather, it is the consequence of the more running space they have available triggered by minor defensive tactics from their opponents. Additional accurate analysis of the performance would be required to observe other factors so to have a more correct description of the players running intensity during the match. The main high-intensity variables are acceleration and deceleration, considering that the running speed at the beginning of the match is of intense energy.

A more detailed analysis model for assessing performance has been developed from these observations. The analysis of a large amount of data stored in the K-Sport® *database* (Leader in statistical analysis in elite soccer) obtained from a sample of over 10.000 matches a year, has helped define the following parameters:

- Mean total distance covered: 11Km;
- Mean distance at high acceleration, with 2m/s²: 650mt;
- Mean distance at high deceleration, with -2m/s²: 650mt;
- Mean distance at high speed, with 16 km/h: 2Km;
- Mean distance at high metabolic power: with 20W/Kg: 3Km.

The above data refers to elite players; with amateur players the average figures will obviously be lower. This model has been developed on an average statistical figure obtained by observing the players in their different roles (Izzo and Sopranzetti 2014): what has emerged is that, for example, midfielders are the players that cover the greatest distance.

Based on the data considered, it is clear that soccer players do not cover the total distance at the same speed. They frequently change running speed and perform several sprints, i.e. running over 20Km/h. Specifically, they perform on average 2-4" sprints every 90", that is 1-11% of the total distance covered.

Protocol

The experimental research, object of the current study, whose aim has been to analyse acceleration and deceleration capacity decrease in repeated sprints, will now be evaluated.

Tools and Research Methods

As mentioned above, GPS 10Hz devices (K-Sport), which were placed into a special garment worn by the athletes tested, were used.

The general GPS data were transferred onto a computer and elaborated through a spreadsheet (Microsoft® Office® Excel®) and a specific software (Prozone Kinetik®), able to process raw data through mathematical formulas specifically studied to evaluate acceleration, speed, metabolic power and heart rate. The software can only be used with GPS devices supplied by the same company. The software helps to assess acceleration, speed, metabolic power and heart beat through parameters calculated with mathematical formulas too. Among these, particularly significant are those that correlate the four factors with time (Fig. 2), distance covered (Fig. 3) and energy consumption (Fig. 4).

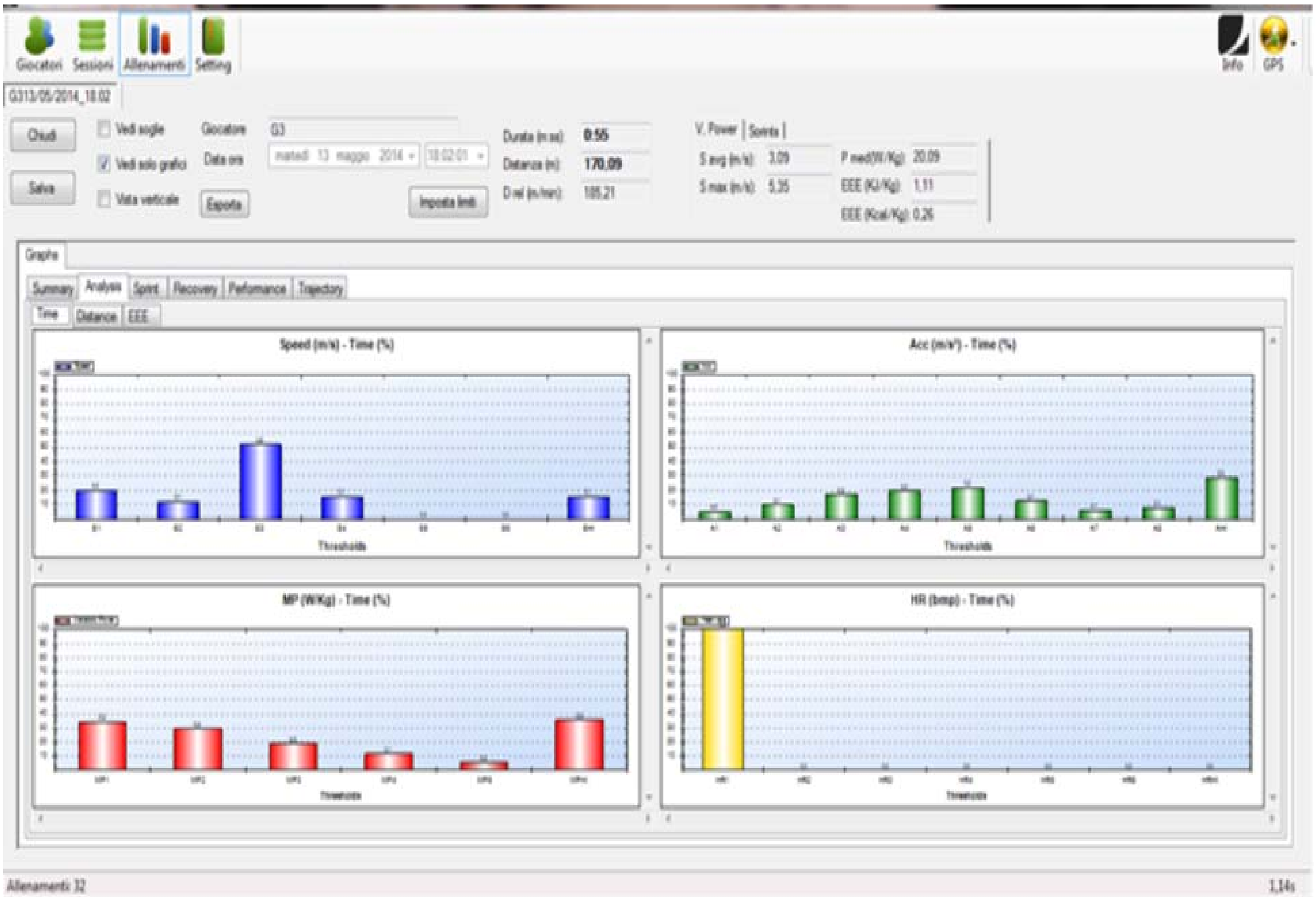

Fig 2: The above screen page shows the data related to the correlation between time and: speed (blue), acceleration (green), metabolic power (red) and heart rate (yellow), and an indication of the percentage of time spent for each parameter regarding the previously established thresholds.

Fig 3: The above screen page shows the data related to the correlation between the total distance covered and: speed (blue), acceleration (green), metabolic power (red) and heart rate (yellow), and an indication of the percentage of distance covered for each parameter regarding the previously established thresholds.

Fig 4: The above screen page shows the data related to the correlation between total energy consumption and: speed (blue), acceleration (green), metabolic power (red) and heart rate (yellow), and an indication of the percentage of distance covered for each parameter regarding the previously established thresholds.

Method

40 amateur athletes, aged between 17 and 19, and playing in the junior soccer league (Regional Category), contributed data to this research program. A familiarization session with the test and the technology was suggested to the athlete, before the actual test. On the day of the test the athletes performed a complete warm-up session to prepare for the test. An operator supervised the test, timed the recovery sessions and informed the athletes of the start of another stage through a beep signal.

Test set up

In the first stage of the investigation with GPS technology, the "Capanna Test" was used to evaluate whether there was a significant decrease detectable by the graph curve, which was much lower in the last sprints than in the first on both acceleration and deceleration.

It was thought, however, that, considering its characteristics, the "Capanna test" should be adapted to make it more useful for the proposed research study.

The next stage was to modify the test by modulating the repeated sprints, the meters covered, the recovery periods as well as the procedure itself. All this was carried out to achieve a new test which would demonstrate the research initial thesis statement.

The exercise protocol consisted of 5 repeated sprints, instead of 6, adjusting covered distance and recovery period after each set. The 5 repetitions were managed as follows:

- 5x10mt with 20" recovery
- 5x10mt with 15" recovery
- 5x10mt with 10" recovery
- 5x5mt
- with 10" recovery
- 5x5mt with 5" recovery

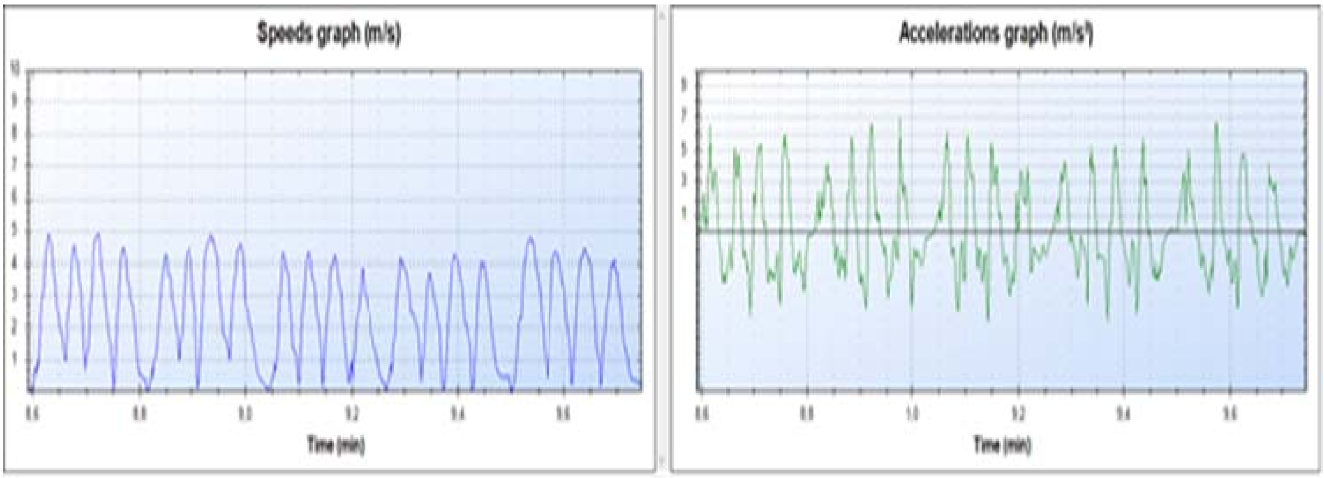

Fig 5: The above graphs show speed trends (blue curve) and acceleration trends (green curve) in a 5x10mt test with 20" recovery.

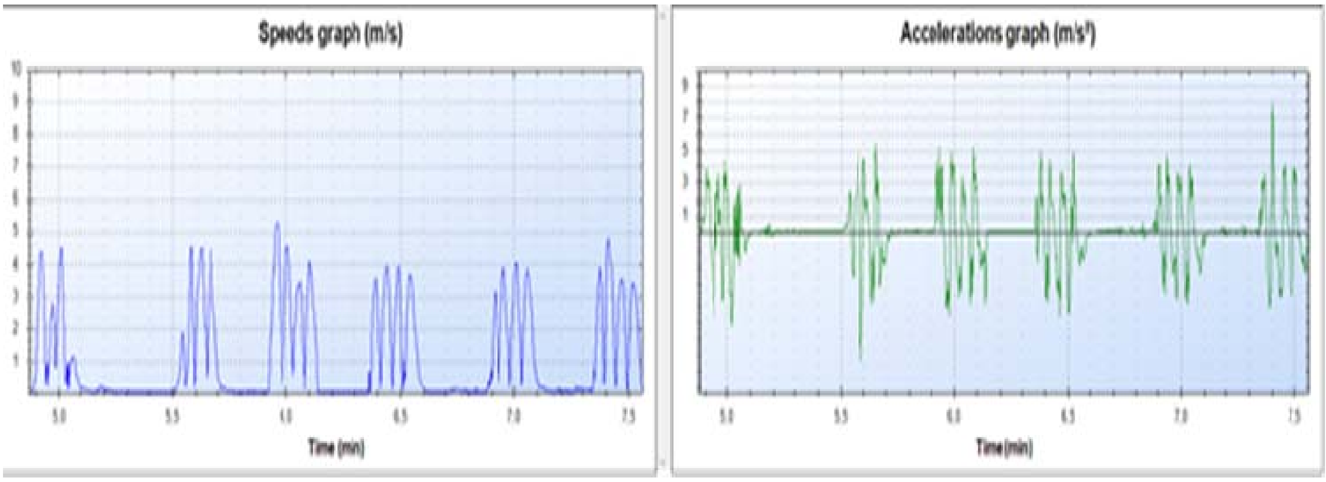

Fig 6: The above graphs show speed trends (blue curve) and acceleration trends (green curve) in a 5x10mt test with 15" recovery.

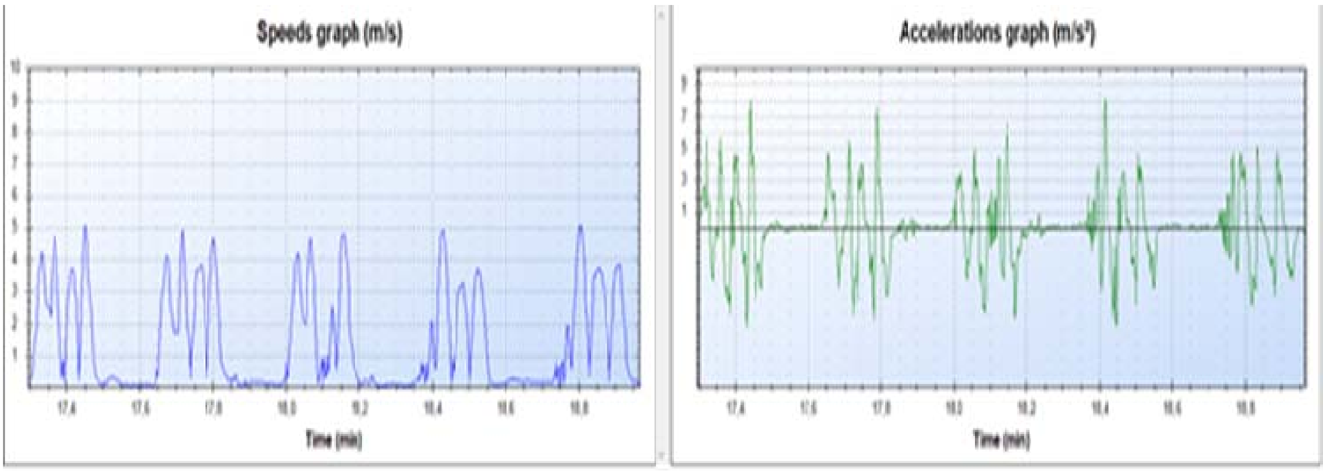

Fig 7: The above graphs show speed trends (blue curve) and acceleration trends (green curve) in a 5x10mt test with 10" recovery.

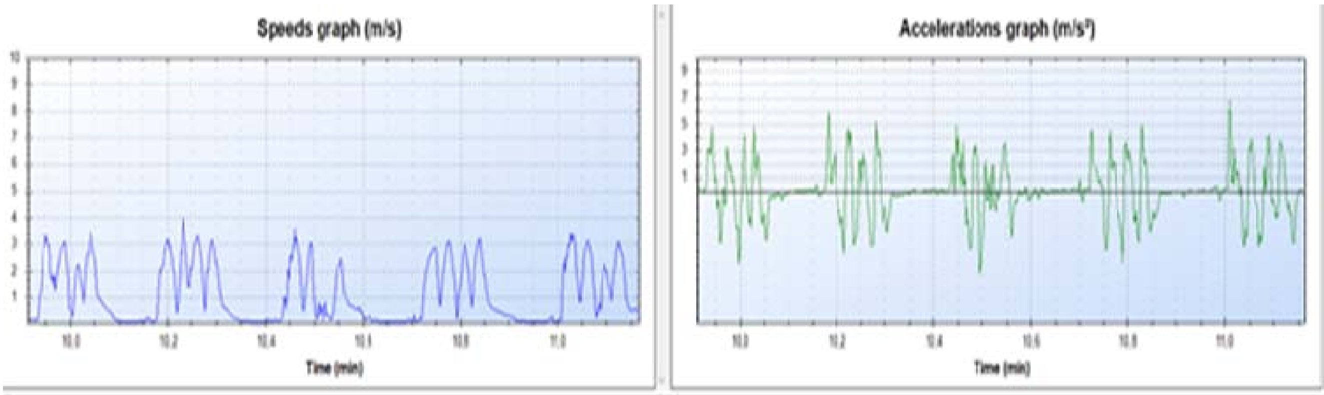

Fig 8: The above graphs show speed trends (blue curve) and acceleration trends (green curve) in a 5x5mt test with 10” recovery.

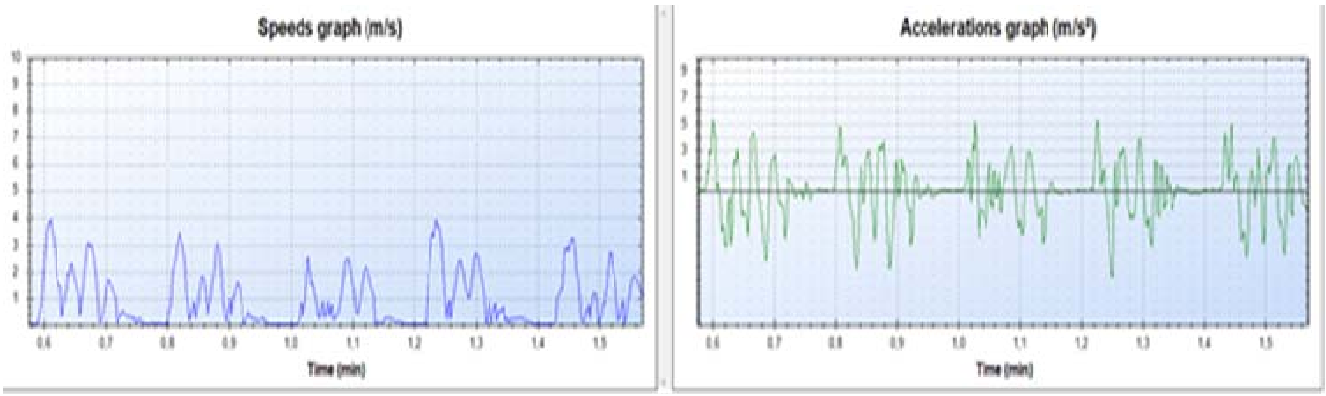

Fig 9: The above graphs show speed trends (blue curve) and acceleration trends (green curve) in a 5x5mt test with 5” recovery.

Despite these changes, the shuttle run tests did not contribute positively to the research. Through an accurate analysis of the graphs and the elaboration of GPS data, it was observed that in the speed trend there was never a sharp deceleration when the athlete changed direction. It was hypothesized that this could depend on several factors, considering though that change of direction in itself was the major cause of the lack of significant results.

In addition, when the acceleration and deceleration curves were analysed, it was observed that there was never a real decrease in performance.

Being sure of the existence of a decrease in acceleration and deceleration, detectable in the curve analysis, the research investigation was furthered by modifying the execution test. The shuttle test was replaced by a repeated sprint start-slowdown-sprint start-slowdown test without changes of direction. This choice clearly implied the elimination of one of the most important parameters of a football player’s performance, the change of direction. The test modification was justified considering the most important physical parameters of the research, namely accelerations and decelerations, which were still present in the new proposed test execution; thus, it was also possible to assess the athlete’s capacity to slow down.

The new test consisted of 6 repeated sprints (5+5+5+5+5+5 mt) with 20” recovery between sprints. The test presupposed that the slowing down phase after every 5 mt sprint should be complete and possibly the most efficient for the athlete, who was covering less possible distance. A 5 mt distance for each sprint start was chosen because all the previous tests had shown that the first 5 mt of every acceleration were sufficient for the proposed research. Furthermore, a recent study has demonstrated that a peak in acceleration occurs during the initial seconds of the sprint, followed by rapid decrease.

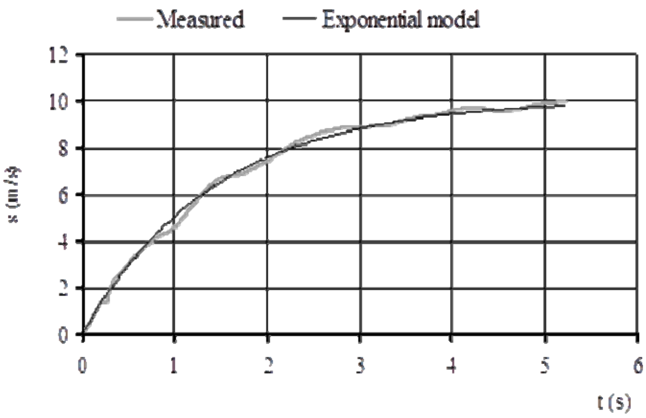

Fig 10: Analysis of acceleration against time, in a 30 mt standing start sprint; “s” indicates velocity and “t” indicates time (Di Pampers, *et al.* 2005).

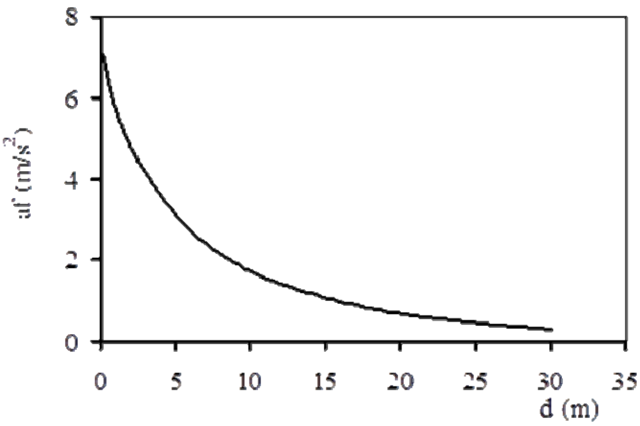

Fig 11: Analysis of acceleration against distance covered in a 30 mt standing start sprint; “af” indicates acceleration and “d” the distance covered. (Di Prampero, *et al*. 2005).

The number of repeated sprints (6) and recovery time between sprints (20) was thought to be the optimal choice to show evidence of fatigue, taking into account the test initially examined (the Capanna test).
After the purely theoretical evaluation of the test trials, the research moved on to the actual field tests.
The test was performed by selected athletes.

Result Analysis
After the field test the GPS data was downloaded onto a PC. For the analysis, the data was then uploaded on the specific software (Prozone Kinetik®), previously illustrated. (Data subsequently re-elaborated through Excel).
The graphs shown in the research study refer to a part of the total graphs examined, as they proved to be more meaningful and clear for the explanation.
The first step was to analyse the acceleration and deceleration curve trends in the tests performed (**Error! Reference source not found.**). Specifically, the repeated sprints in each test were separated so as to have overlapping curve trends, and verify the occurrence of a possible decrease in acceleration and deceleration.

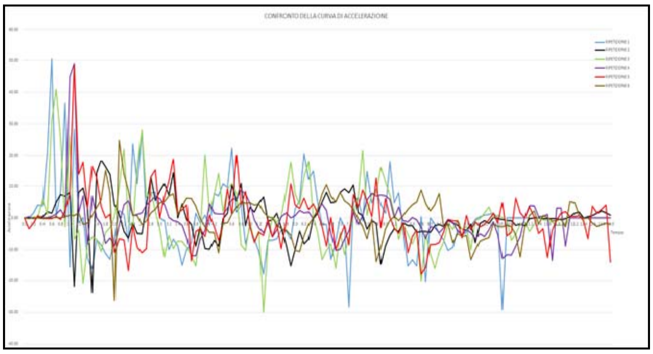

Fig 12: Overlapping of acceleration/deceleration curves in the six test repetitions.

For a more accurate analysis, the curve trends of each repetition, of every single test, were compared to the first one. The reason for thus was to verify if it were possible to confirm the research hypothesis: fatigue would clearly show a decrease in the capacity to accelerate and decelerate. The following graphs (**Error! Reference source not found.**, **Error! Reference source not found.**) evidence that in the first repetitions fatigue is manifest in the last sets rather than the initial peak.
As for the deceleration curves, a clear decrease is not as obvious as for the acceleration curves. It is however possible to observe a slight decrease in deceleration peaks.

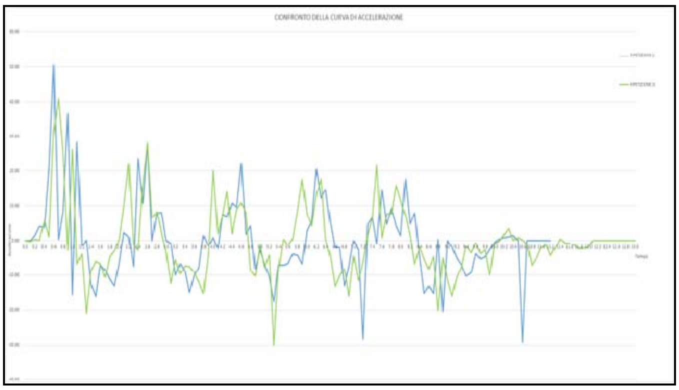

Fig 13: Comparison of acceleration/deceleration curve between the first (blue) and the fifth repetition (red).

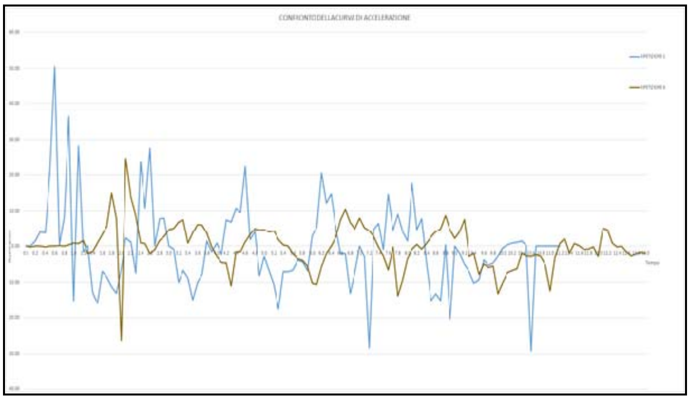

Fig 14: Comparison of acceleration/deceleration curve between the first (blue) and the fifth repetition (red).

In the sixth repetition (Fig. 15) the change appears to be more significant: all acceleration peaks are much lower, including the one in the first acceleration. This last repetition shows a drastic decrease, never observed in the previous ones.
An accurate analysis of the deceleration curves shows that the peaks are lower and deceleration time is slightly longer.

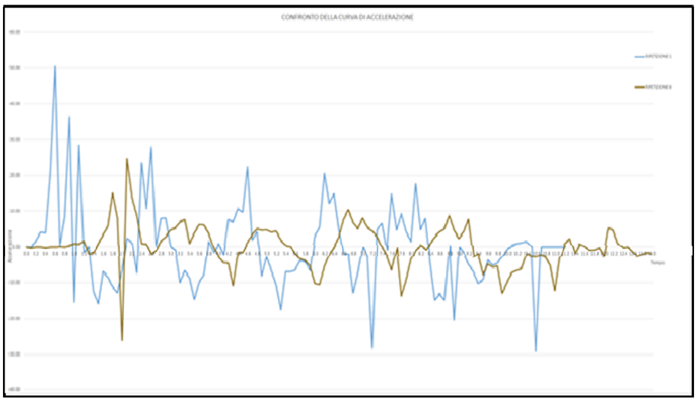

Fig 15: Comparison of acceleration/deceleration curve between the first (blue) and the sixth (gold) repetition.

This first analysis from the observation of the graphs, was followed by a more scientific investigation of the data, focusing particularly on the acceleration peak in each repetition. The following data is what emerged from an exemplifying test (Table 1):

Table 1: Data resulting from an analysis of acceleration peaks.

	Acceleration peak	Number of accelerations above 20m/s^2	Decrease compared to the first repetition
Repetition 1	50,56	8	-
Repetition 3	40,93	8	19,1%
Repetition 5	48,71	2	3,7%
Repetition 6	24,82	1	50,9%

The above data corroborates what has emerged from the previous graphs, which is that repetitions 3 and 5 do not show a particularly significant decrease: when the peak is much lower high-intensity accelerations remain almost the same (above 20m/s^2).
Conversely, in the sixth and last repetition there is a significant decrease both of peak and high-intensity accelerations.
The rapid decrease in performance in the sixth and last repetition of the test, as evidenced in the curve analysis, is corroborated in the value difference by about 51% between the initial maximal peak and the final one.

Table 2: Data resulting from the analysis of deceleration peaks.

	Deceleration peak	Decrease compared to the first repetition
Repetition 1	-29,26	-
Repetition 3	-30	-2,5%
Repetition 5	-17,6	39,9%
Repetition 6	-26,3	10,1%

An analysis of the above data does not allow for an acceptable scientific profile as the decrease is not standardized. (**Table 2:** Data resulting from the analysis of deceleration peaks.

	Deceleration peak	Decrease compared to the first repetition
Repetition 1	-29,26	-
Repetition 3	-30	-2,5%
Repetition 5	-17,6	39,9%
Repetition 6	-26,3	10,1%

).

Conclusions

From the research carried out and illustrated in this paper the following conclusions can be drawn:

- In the acceleration stage there is a clear correlation between the test results and an increase in athletes' fatigue. Precisely, there is a slight decrease which progressively turns into a significant one from the first to the last repetition. Hence, the test to assess the quality of athletes' ability to accelerate after repeated sprints can be considered reliable.
- Conversely, as regards deceleration, the results attained do not allow for definite scientifically proven conclusions. A personal consideration, however, can be expressed related solely to the analysis of the deceleration curves. It can be observed that the deceleration distance, ergo slowing down, increases slightly at every repetition. This could be attributed to first signs of fatigue, as for acceleration.

Overall the test can be held as qualitatively reliable for both the factors above mentioned, which was the object of the current study, and corroborated by mathematical data through decrease index evaluation (see Table 1), for the assessment of acceleration only.

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