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The study of acceleration capacity decrease in repeated 30m sprints

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Abstract
The purpose of this study (in collaboration with Prozone and K-Sport) was to highlight acceleration and deceleration (sudden drop in maximal velocity) capacity in repeated sprints by means of field test results. The test consisted of 5x30m sprints, and the 20 selected athletes were monitored through the use of wearable 10Hz GPS devices, able to measure acceleration and deceleration parameters, which would otherwise not be detectable through photocells. The purpose of the study was to evaluate acceleration and deceleration capacity in repeated sprints (RSA) and high-intensity performance, with only 25 seconds rest between each sprint, by examining the speed and acceleration graphs as well as their peaks when signs of fatigue set in, through GPS devices. To verify repeatability the subjects were asked to perform the test several times, on a short term basis within a 24 hour period, and weekly on a long term basis. The test has proved to be a reliable means to measure capacity and performance as well as each subjects' own performance ability improvement. GPS data have, for the first time, shown the variation of acceleration and speed peaks, and their trend during intermittent or high-intensity performance.

Keywords: Acceleration, deceleration, sprints, GPS, RSA.

Introduction
The purpose of this study was to show acceleration capacity and speed peak decrease in subjects submitted to a test of 5x30m sprints, by examining the respective graphic trends measured through GPS technology (K-GPS, 10 Hz) rather than through photocells, used in past research studies. In fact, photocells can only identify time, which is not a variable indicative of the capacity of an athlete to accelerate as it represents a mean value only. The test was submitted to 20 athletes between 20 and 25 years of age, with an average height of 180cm and a weight of 85kg. The study evaluates the ability to perform repeated sprints during a training session, with minimal time of recovery between each sprint, by examining the decrease in acceleration and speed peak trends as a consequence of fatigue, through GPS devices worn by the athletes.
In order to verify repeatability the subjects were submitted to the test several times (with no regular intervals). For short term repeatability the subjects performed the test in the same session and within the following 24 hours; for long term repeatability the subjects were submitted to weekly tests and evaluations. The test has proved to be a reliable and repeatable means to measure and evaluate performance and its development in the tested subjects. GPS data were collected and analysed through the use of K-Fitness software (K-Sport), and they basically enabled the researcher for the first time to reach accurate results besides the different physiological characteristics of each athlete, as well as those techno-related characteristics of the specific sport. Furthermore, the test analysis has proved to be reliable in accurately identifying athlete speed peak variations, and in observing during field tests, real acceleration trend in intermittent, high-intensity activity and consequent decrease when fatigue occurs.

State-of-the-art
The ability to perform repeated sprints has been studied by many scholars who, through the use of different technological devices, have attempted to identify the relation between the ability itself and high level performance in those sports where repeated sprint ability is required (Oliver, Armstrong and Williams 2007) [57]. GPS devices have been used for some years in team (for group and individual analysis) and endurance sports to assess performance during

competitions and, particularly, during training sessions. GPS devices have also proved to be a useful and very reliable method to measure RSA (Repeated Sprint Ability) and assess performance in terms of acceleration and speed (Barbero-Alvarez, *et al*. 2010) [13]. Soccer, like most team sports, consists of a running activity with variations on speed and direction. (Anzil 1984, Ali and Farrely 1991, Balsom 1994, Bangsbo 1994, Banister 1991, CONI 1995) [5, 8].

Until recently, a soccer performance model, which resulted from the match analysis carried out during the actual match, was classified as follows (Anzil 1984, Tumilty 1993, Ali e Farrely 1991, Balsom 1994) [5]:

- stance
- walking (4 km/h)
- jogging (8 km/h)
- moderate speed running (>12 km/h)
- average speed running (>16 km/h)
- sprinting (>20 km/h)
- backward running
- total performed distance (Km)

To regard running above 20km/h as high-intensity activity, without giving any kind of metabolic and performance indication that would reflect the real high or low intensity of a performance (Bangsbo 2002, Bangsbo, Norregaard and Thorsoe 1991, Barbero-Alvarez, *et al*. 2008) [7, 12, 14] is still an incorrect, or rather incomplete, practice because the acceleration and deceleration values have not yet been taken into consideration.

In recent years, research studies have actually been conducted on elite soccer teams taking part in top-level European Championships, in Champions League and National League Cups (Krustrupp and Bangsbo 2001, Mohr, Krustrupp and Bangsbo 2003, Drust, Atkinson and Reilly 2007, Gabbet and Mulvey 2008, Fiorini, *et al*. 2014) [45, 53, 36, 33] where what emerges is not only a great amount of high speed running activity but also the value of acceleration as a particular feature of the sport competition.

To this end, a study carried out by Di Prampero (Di Prampero, Fusi, *et al*. 2005) [60], on a few meter sprint from a standing start has indeed proved to be scientifically significant. The study illustrates how acceleration from a standing start becomes incredibly high in the first meters, approximately 6 m/s^2, which allows the athlete to reach a speed of 18-20 km/h after 1 second with a very rapid decrease afterwards (Di Prampero, Capelli e Pagliaro 1993, Di Prampero, Fusi, *et al*. 2005) [60].

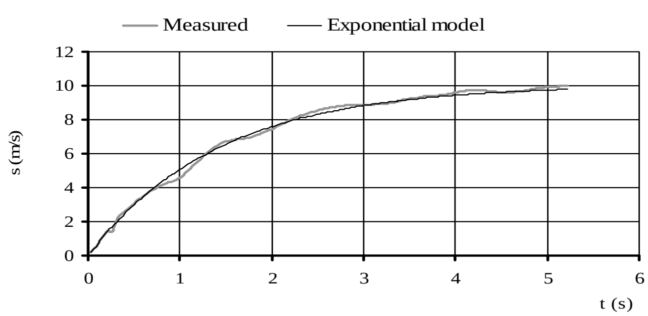

Fig 2: analysis of a sprint, acceleration in relation to time (Di Prampero, 2005).

Figure n. 3 shows that after 10m acceleration, which depends directly upon the net force (F = M x A), has already decreased to $2ms^{-2}$ (Plamondon and Roy 1984, Di Prampero, Fusi, *et al*. 2005).

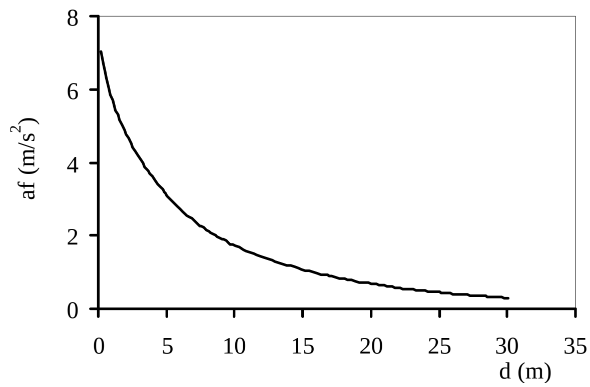

Fig 3: acceleration peak and decrease (Di Prampero and Pagliaro 1993)

Although sprinting represents only 10/12% of the distance covered during a soccer match, this can have a significant impact on the development of the game and match final result, as that 10/12% includes most of the components related to a positive performance (Meckel, *et al*. Publish Ahead of Print). In fact, many studies have corroborated the importance of RSA (repeated sprint ability) in sport performance (soccer performance, especially) as well as the correlation between sprinting capacity and performance through, for example, evaluation tests. (Silva, Guglielmo, *et al*. 2014., E. Rampini, *et al*. 2007., Castagna, D'Ottavio and Abt 2003.,Strudwick, Reilly and Doran 2002, Abrantes, Macas and Sampiao 2004., Tatcher and Batterham 2004., Lakomy 1987, Nicholas, Nuttall 2000., Spencer, *et al*. 2004, Gabbett 2010., Psotta, *et al*. 2005, Wragg, Maxwell and Doust 2000., Ekblom, Applied physiology of soccer 1986, Balsom 1994, Bangsbo 1994, Reilly, Bangsbo and Franks 2000, Krustrup, Mohr, *et al*. 2003., Lèger, Lambert and Goulet 1984) [69, 64, 21, 29, 74, 47, 55, 79, 5, 8, 44].

Amongst the most recent tests there is the l'Intermittent Endurance Running (INTER) which has been developed to evaluate the capacity to perform repeated sprints focusing on one intense field test (Currel e Jeukendrup 2008) [28]. (Silva, Guglielmo, *et al*. 2014., E. Rampini, *et al*. 2007., Castagna, D'Ottavio e Abt 2003., Strudwick, Reilly e Doran 2002, Abrantes, Macas e Sampiao 2004., Tatcher e Batterham 2004., Lakomy 1987, Nicholas, Nuttall 2000., Spencer, *et al*. 2004, Gabbett 2010., Psotta, *et al*. 2005, Wragg, Maxwell e Doust 2000., Ekblom, Applied physiology of soccer 1986, Balsom 1994, Bangsbo 1994, Reilly, Bangsbo e Franks 2000, Krustrup, Mohr, *et al*. 2003., Lèger, Lambert e Goulet 1984) [69, 64, 21, 29, 74, 47, 55, 79, 5, 8, 44].

Table 4: an example of the different stages in an INTER test

Movement stages and number of repetitions for each completed stage	
Shuttle run (20m)	6
Agility Sprint (47m)	1
Recovery (35sec)	1
Shuttle run (20m)	6
Straight line sprinting(25.3)	1
Walking (35m)	1
Recovery (10sec)	1
Shuttle run (20m)	6

Though soccer is mostly an aerobic sport (Bangsbo, Football (soccer) 1994, Drust, Atkinson and Reilly 2007) [8,, its anaerobic parameters and its elements like sprinting, jumping and muscular strength are crucial (Ekblom, Applied physiology of soccer 1986), and have to be regularly tested to determine a player's strength and weaknesses, or rather, to assess the appropriateness of specific training protocols (Svennson e Drust 2005) [73]. What must be stressed is that field tests, for soccer and team sports in general, should not be taken as predictors of effective match performance. It is indeed very complex to separate the singular components of the physical performance when the overall demand and game urgencies are actually very complex and changeable (Svennson e Drust 2005) [73], and some tests do insert components with the ball to make the test more accurate and reliable (Cox, *et al*. 2002, Chamari, *et al*. 2005, R.E. Izzo 2013) [27, 23]. These tests, however, could be influenced by the capacity to manage and control the ball thus conditioning the match result, and not enabling to determine specific athlete "fitness" (physical conditions) parameters. Other tests include Intermittent run (Silva, Guglielmo, *et al*., 2011, Krustrup, Mohr, *et al*. 2003, Lemmink, Verheijen and Visscher 2004) [70, 44, 49], single straight line sprinting (Gabett 2010, Psotta, *et al*. 2005) or a number of sprint and agility exercises (Sporis, *et al*. 2010) [72].

Nowadays, the gaps left by field tests are filled by very accurate and reliable analyses of metabolic parameters released during performance and not only, thanks to the development of new technologies used in performance analysis (Reep 2002).

The use of GPS devices has lead to a major focus on an individualized evaluation of the performance. A study published in 2014 reported reference values of soccer performance during official 90-minute matches where the players were asked to wear GPS equipment, which was a new method to evaluate performance, and much more accurate than video interpretation where small errors could not be detected (Fiorini, *et al*. 2014) [33].

Despite these seemingly accurate results, there are, however, problems connected mainly to satellite signals when GPS is applied, specifically to sampling frequency (e.g. how much can be detected in one second), and to interference related to the actual architecture of the sports field.

As can be observed from the graphs in Fig.5 and Fig.6, which compare a Radar with a 4 Hz and 5Hz GPS receiver (M. Marcolini 2014, K-Sport 2014), a GPS device is able to provide more accurate data as it is more sensitive to movement (Larsson 2003, Barbero-Alvarez, *et al*. 2010) [48, 13].

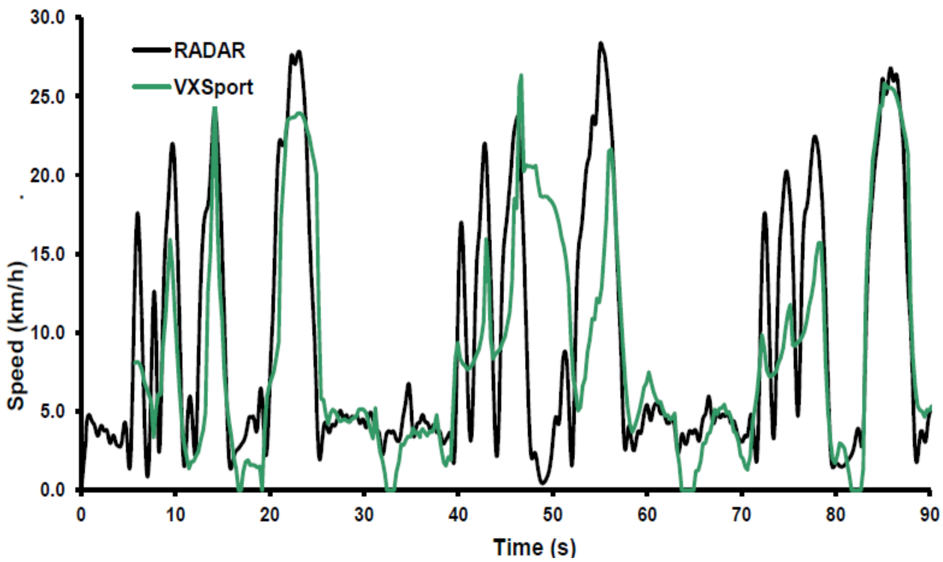

Fig 4: Differences in GPS (K-Sport) and RADAR (K-Sport 2014) monitoring

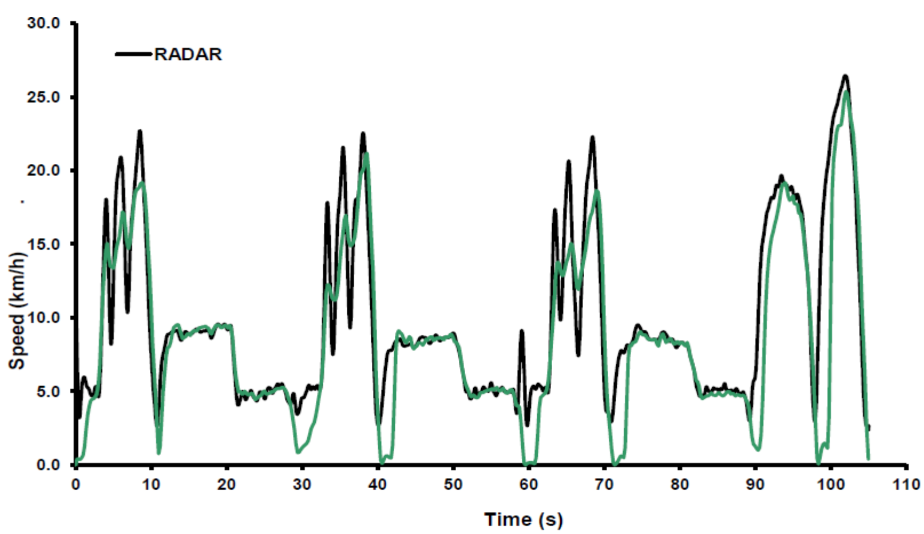

Fig 5: Differences between GPS 5Hz and RADAR (K-Sport 2014) monitoring

What can be observed is an increased sensitivity and precision when moving from a 5Hz GPS receiver (K-Sport 2014) (Fig. 5) to a 10Hz one (Fig. 6).

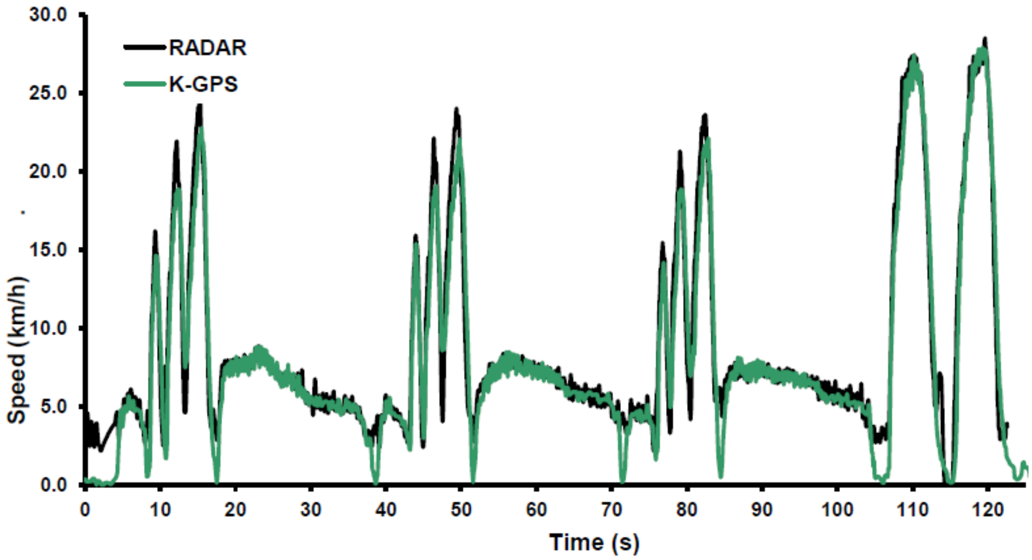

Fig 6: GPS 10Hz (K-Sport) and RADAR (K-Sport 2014) monitoring

The global positioning system (GPS) applied to sport performance must provide accurate measurements so it is preferable to use GPS receivers with at least nine channels. An equally important feature is related to the capacity to store data: for example a 10Hz GPS is able to collect maximum data every 0.1 second (Larsson 2003) [48]. With this system, which is triaxial accelerometer-based, it is possible to establish running direction, as well as the presence of any kind of obstacle (Carling, Christopher, *et al*. 2008) [20].

As previously mentioned, GPS receivers are also utilized as tools to improve performance analysis in some field tests, as in this case with the RSA test (Repeated Sprint Ability), by particularly assessing acceleration during sprinting and speed decrease.

The “5x30m” test aims at evaluating efficiency in performing maximal sprints with reduced recovery time (Francini, Castellini, *et al*. 2000) [35]. A good test result may lead to a more successful performance. The test consists of 5 maximal 30m sprints and a 30 second rest time between each sprint (Castellini, *et al*. 2000, Prampero, Fusi, *et al*. 2005, Francini) [35, 60]. Acceleration ability and speed decrease are key factors in effectively evaluating an athlete’s ability to perform repeated sprints (Prampero, Capelli and Pagliaro 1993, Prampero, Fusi, *et al*. 2005) [60], and also in being able to identify elite and sub-elite performances (Ekblom 1986, Ali and Farrally 1990, Bangsbo, Mohr and Krustrupp 2006) [2, 45], otherwise not detectable when using photocell timing gates.

Tools and Method

The capacity of repeated sprints is relevant to team sports performance like soccer (Abrantes, Macas and Sampiao 2004, Rampini, Bishop, *et al*. 2007, Rampini, Coutts, *et al*. 2007) [62, 63]. A number of research studies have documented that high-intensity activities, as is sprinting, clearly and inevitably decrease during the game (Balsom 1994, Bangsbo 1994) [5, 8]. Only 3% of the athletes submitted to the research tests were able to perform adequately (Aandstad and Simon 2013, Basquet, *et al*. 2002, Krustrup, Aastrupp, *et al*. 2002) [1, 15, 44], and, during an actual game, professional players performed at a high-intensity level only in the last 15 minutes of the competition.

Many research studies have also shown that the players who are involved in the second half of the match are able to sprint and run much more intensively than those who play the whole match (Anzil 1984, Balsom 1994, Bangsbo 2002) [5, 7].

In the present study 20 athletes (aged between 21 and 25, 175cm tall and with a weight of 80kg), at different time intervals (from 2 to 10 days), performed 5 5x30 repeated sprints with an active recovery period of 25 seconds, after they had familiarized themselves with the test and the technology used.

The familiarization procedures were done during physical fitness sessions prior to the beginning of the League season, and during scheduled recovery periods during the Premier League.

To establish repeatability on a short term basis the GPS (K-Sport 2014) data of the trials in one same session and in the following 24 hour sessions were compared to verify whether there were inconsistencies in the performances or in the data recorded due to the athlete or the test itself.

Long term repeatability was determined by assessing the four test trials which the subjects had to repeat weekly, and evaluating them week by week.

Active recovery between performances was rigorously timed through two chronographs (two examiners, placed at each end of the running track) and a satellite watch, and it was calculated in a way that it led to a natural decrease in performance.

Acceleration and speed decrease were assessed through 10Hz GPS receivers (M. Marcolini 2014, K-Sport 2014), placed into special garments on the back of the athletes, and which were able to record data of even the most subtle movements.

The analysis of recorded data was possible through a specific software (Prozone 2014, K-Sport 2014) able to transmit all stored data, and enabling the researcher to select only the data useful for the present study.

The subjects were asked to perform each trial sprint with maximum physical effort in order to induce natural decrease in performance.

In this type of shuttle run it is possible to observe the other important factor in team sports which distinguishes them greatly from straight-line running: decrease in speed peak and rapid deceleration.

For this reason, the present research focused especially on the study of acceleration and speed decrease in a test consisting of 5x30m repeated sprints by utilizing a 10Hz GPS (Gps K-Sport): a much more accurate device than both the 1Hz one, which would not be able to detect both acceleration and speed decrease, and the 5Hz GPS, which would have been able to detect them partly.

Discussion and Development

As shown in the acceleration and speed graphs below, it was possible to observe and establish with greater certainty a real decrease in the subject's ability to accelerate with consequent gradual decrease in speed peak.

From as early as the second sprint one can observe a speed decrease, which reaches a certain plateau in the third and then starts decreasing further until the last sprint with the lowest peak, both qualitatively and quantitatively.

Regarding acceleration, what is noticeable is a decrease in acceleration peak due to a decrease in the subject's ability to perform maximum acceleration as the test progresses.

The graphs also show a decrease in acceleration intensity peak as well as a decrease in time, namely the ability to protract maximum acceleration in time, which decreases keeping a gradually lower time with gradually more modest peaks.

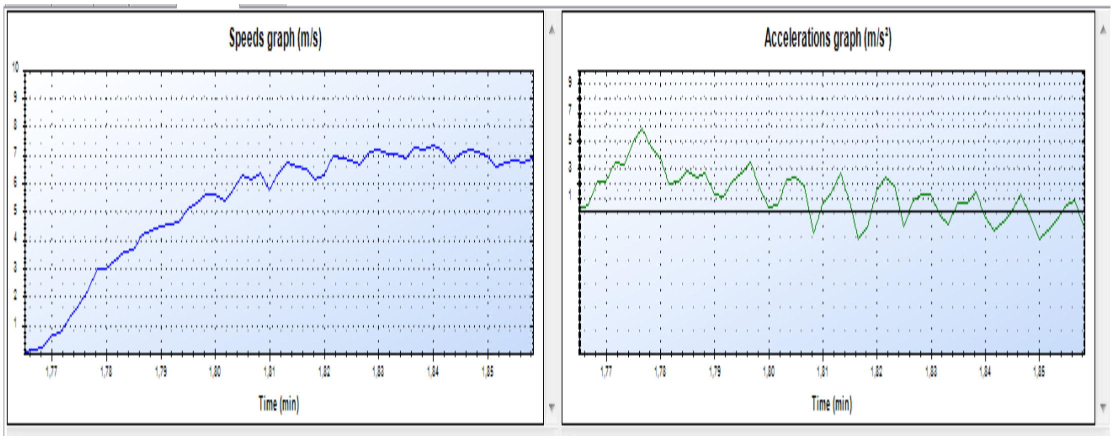

Fig 7, 8: First 30 m sprint (Sprint. n. 1)

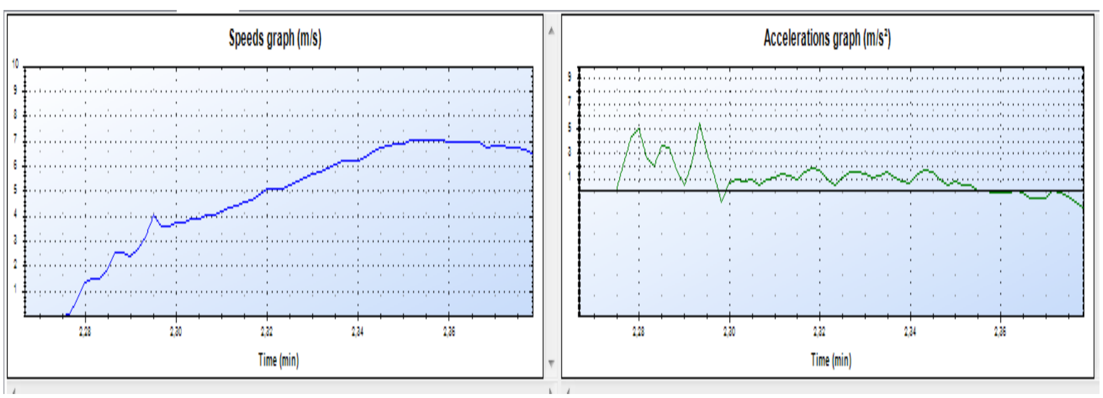

Fig 9, 10: Second 30 m sprint, preceded by a 25 second recovery time (Sprint. n. 2)

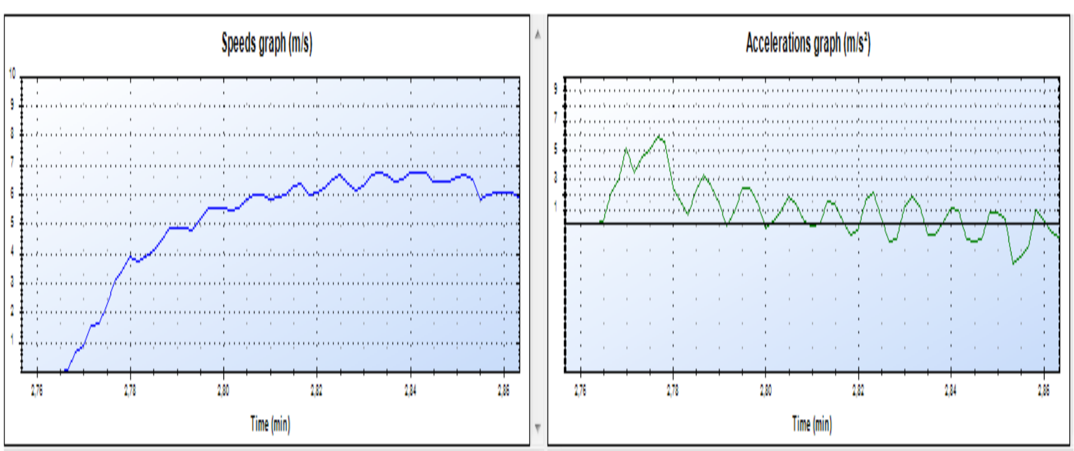

Fig 11, 12: Third 30m sprint, preceded by a 25 second recovery time (Sprint. n. 3)

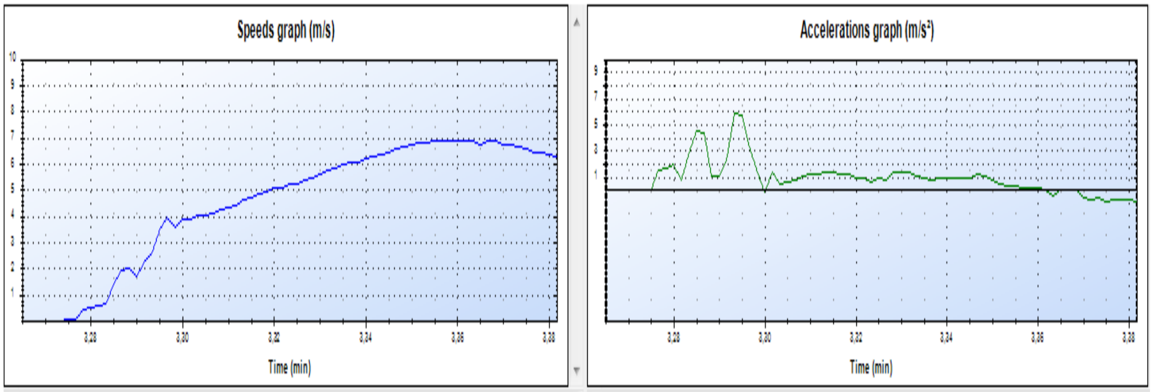

Fig 13, 14: Fourth 30 m sprint, preceded by a 25 second recovery time (Sprint. n. 4)

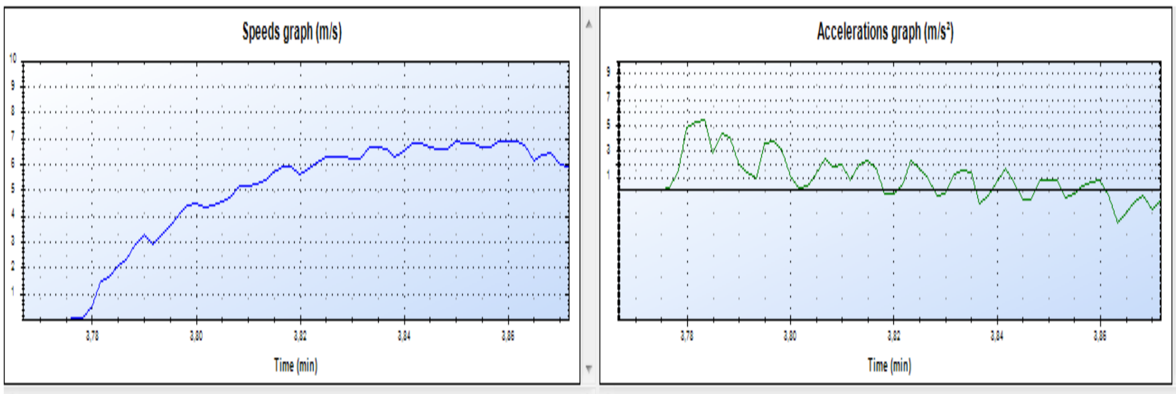

Fig 15; 16: Fifth 30 m sprint, preceded by a 25 second recovery time (Sprint. n. 5)

In line with the studies by Di Prampero (Di Prampero, Capelli and Pagliaro 1993, Arsac and Locatelli 2002, Di Prampero, Fusi, *et al*. 2005) [4, 60], the graphs show that maximum acceleration peak occurs in the first five metres of the tests with different subjects (three examples below)

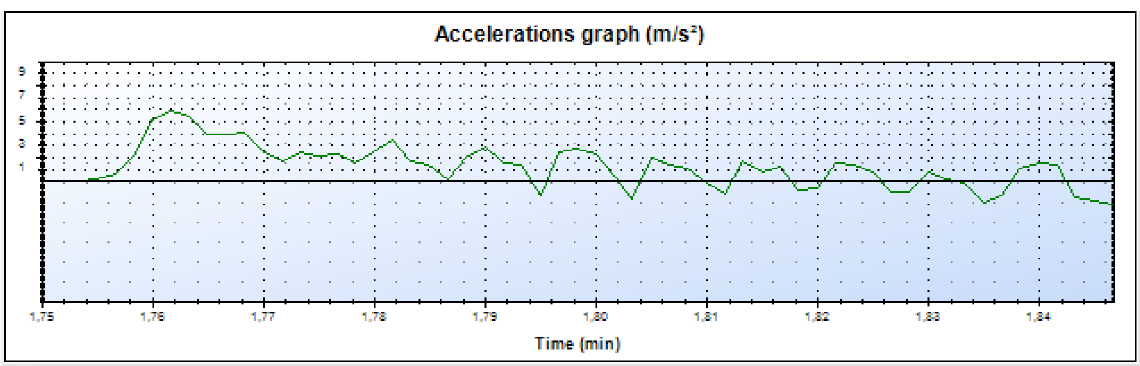

Fig 17: Acceleration curve measured by GPS K-Sport (Sprint Subject n°8)

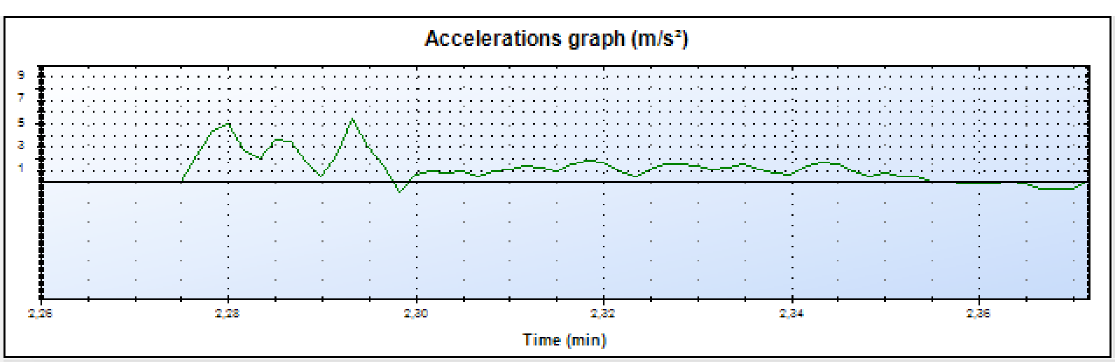

Fig 18: Acceleration curve measured by GPS K-Sport (Sprint Subject n°5)

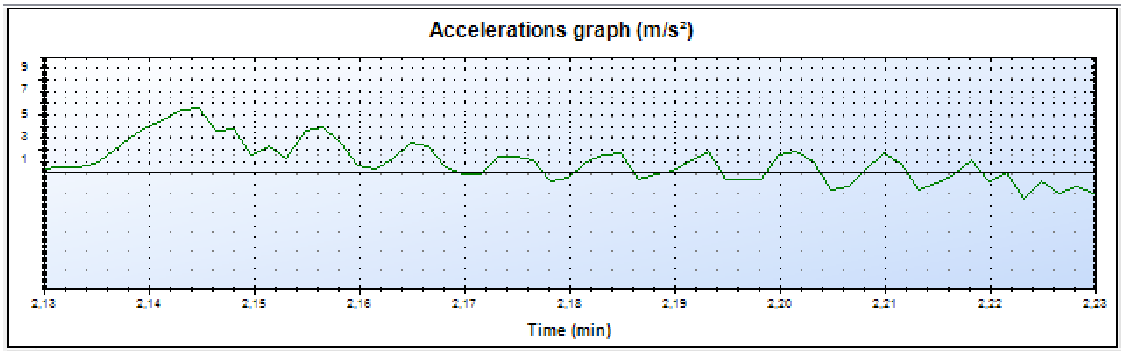

Fig 19: Acceleration curve measured by GPS K-Sport (Sprint Subject n°3)

Conclusions

The results of the present study have demonstrated that the test consisting of 5x30m sprints presents good absolute and relative repeatability on subjects on a short term basis (day-to-day-24 hours), or on a long term weekly basis between test trials.

This is not true for a Yo-Yo Test (Krustrup, Aastrupp, *et al*. 2002, Bangsbo, Yo Yo test 1996) [44, 10], or for the INTER test (Aandstad and Simon 2013) [1] where the unreliable component of signal/noise ratio could greatly affect data recording outcome, and not even for a shuttle run test (Bangsbo 1994) [8], where the subject's ability to decelerate well is greater than the ability to perform repeated sprints or to perform effective powerful sprints.

On the other hand, there are several problems in a shuttle run continuous test like, for example, a 5x5m sprints or a 5x10m sprints. The first problem is related to GPS capacity to detect a number of very fast changes of direction in an extremely limited space like 5 metres.

Another problem is in acceleration ability itself. As emerges in the excellent study by Di Prampero (Prampero, Capelli and Pagliaro 1993), maximum acceleration is reached in the first 5 metres of a stride and, if within these 5 metres the subjects are required to change direction, they will not be able to reach maximum acceleration. The same problem will occur in a 5x10m test because the capacity to modulate acceleration in order to perform effective deceleration is much more significant than both the sprint itself and the capacity to accelerate. The favourable signal/noise ratio, that is the ratio between results and obstructive factors (for example, evaluation, calculations and movement mistakes) will consider the 5x10m test sensitive to detecting training-related longitudinal variations in repeated sprint ability. The great demand of acceleration and high speed during the different phases of play should lead to consider the need to use straight line running at average speed both during the test and during training sessions. This could also be a way to make the players recover because straight line running at average speed would not cause muscle fatigue, nor the players would feel stressed from the point of view of control management. The choice of physical exercise and its effectiveness should be made by evaluating how similar it is to the model in terms of applied force, frequency and specific coordinating factors. A good head and preparatory coach (in this order respectively) should alternate regeneration moments through average speed running sessions, which have general objectives, with other specific-aimed stages where the athletes are subject to muscular and metabolic coordination efforts based on the performance model, and even higher than the model itself. This sort of test appears to be an appropriate method for measuring prolonged repeated sprint ability with quite a good degree of repeatability.

A higher ability to perform repeated sprints is related to a higher competitive level as well as to high levels of physical fitness and endurance performance, which have implications for training and team strategies. The results suggest that the collected data are comparable to what occurs in a performance during team sport competitions.

Applicative suggestions

Head and preparatory team sport coaches need to focus once more on athlete performance, which seem to have been undermined in the last 20 years. Resorting to practices borrowed first from other sports and then from an obsessive need for physiological evidence, has resulted in a cultural deficiency on attention to a performance model and performance itself. The number of high-intensity stages with repeated sprints occurring during a match is a significant and discriminating factor in high level international and national competitions down to the lowest level leagues, and this has lead to consider reviewing the sport specific performance model. The development of a repeatable and valid system able to detect repeated sprint ability, which would reproduce the most extreme demands of international competition, will enable the coach, the coaching staff and the physical and athletic preparatory team to monitor training and physical quality adjustments, highlighting possible problems and flaws as possible and real discriminators of performance. The above mentioned test could be considered valid in testing not only the capacity to perform repeated sprints with short recovery bouts, but also the aerobic capacity as well as the heart rate of athletes involved in situational sports. Good repeatability and validity can estimate important parameters for the internal load aimed at the development of powerful aerobic and physical performance ability, as requested by the sports performance. Furthermore, the test could reveal itself as a useful method for the coach when arranging training sessions with high- intensity intermittent exercises, for young and adolescent athletes as well as adult and elite athletes.

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