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Detection of physical efficiency and performance of footballers by using GPS and K4

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Abstract

The aim of this Ph.D. thesis is to analyze and compare the player performance model (PPM) of footballers. The thesis tries to analyze the PPM through two different studies. The first part of the project wants to analyze the internal effort of footballers comparing the metabolic power (MP) approach of Osgnach and Di Prampero derived from the external load with use of GPS or video tracking system, with the real metabolic effort gained with a portable metabolimeter. Two different protocols were used. First protocol was performed on 20 amateur footballers from 7Th Italian League (Age: 27,3 ± 3,3, eight: 1,77 ± 3,4 and weight: 80 ± 4,5). Subjects were running 10 minutes with two different velocities 8 Km/h and at 16 Km/h (5 minutes for both) and performing a 5 minutes pause between the two. The type of running was circular asking players to maintain the velocity without performing changes of speed or direction, during the test the players were analyzed with the use of 50Hz GPS (K-Sport Universal, Italia) and a portable metabolimeter Cosmed K4 b2. The second protocol was performed on 20 semi-professional football players (Age: 26,3 ± 3,6, eight: 1,78 ± 4,5 and weight 77 ± 4,3) from a football team of 4Th Italian Championship league. Change the sample was important in order to investigate the possible differences that can be recorded between amateur and semi-professional athletes. The test protocol it was composed in 6 parts (18 minutes) including 2 recovery periods, one at the beginning of the test in order to evaluate the individual basal metabolism and one at the end of the test to determinate the recovery time. The second part of the Ph.D. project was to analyze the PPM of Armenian Premier League during matches using 25 GPS 10 Hz (K-Sport, Montelabbate, Italy), in order to compare data obtained with literature from major European championship. In total were analyzed 25 matches (10 wins, 10 Loses and 5 draws), 33 different players (age 24,3 ± 4,2, eight 1,76 ± 4,2 and weight 74 ± 3,5) and in 270 performances (10,8 for matches).

Introduction

The Performance Analysis nowadays as become crucial in sport, every day we are surrounded by a big amount of data, from T.V broadcasting, newspapers, web pages, and specific apps. We are living in an era of data; the new technologies have entered strongly in the world of sport, trying to measure at first, sport events such as matches, races, championships, and tournament, for individual or team sports. Everything was starting with live handmade notification analysis made by coaching staff during an event in the middle of 90's, with the progress of technology was possible at first to use photos and after videos, in order to execute a more accurate post-analysis. Nowadays is possible with the use of some specific software and hardware analyses events in live, and build one instant report useful to give specific information to coaches. This monitoring is used for tactical, technical, fitness, biomechanical and even psychological performance analysis, clearly every sports has built one, sport specific analysis in order to detect only data that are more important and to avoid the useless amount of numbers. The same analysis can be operated during training in order to compare individual or team performance with competitions events. It seems useful to point out that, in sports specific field and in the dedicated literature, do not exist one universal analysis method that is scientifically recognized as the golden standard of performance monitoring. In addition, even that the evaluation, measurement, control, and creation of corrective parameters according to increase performance cannot be unique. Notwithstanding the great difficulty, complexity, and diversity of the casuistry of gambling, of the psycho-attitudinal problems specific and general sports of individuals as such and as an integral part of a group or team, it is clear that hypothesizing a unique and valid winning method for everyone is not that simple. All this is linked to the great difficulty of controlling the too many different variables that can come into play, in the complex physical psychic evaluation of a single athlete or a team; it is therefore assumed that creating a unique and winning method for everyone is a utopia.

However, which is the final goal of Performance analysis?

Although is not universally recognized one performative method in sport training, no doubts that we can define that the main objective of Performance Analysis is to establish key performance indicators (KPI) that will be useful as parameters aimed at optimizing performance where lacking. The challenge that the coaches will have to face, therefore, will be to determine with scientific clarity specific critical factors that can be improved in absolute, defined strategic variables, which are identifiable as successful or unsuccessful. In order to build one individual guide that has to be different players by players, team by team, championship by the championship, in this way will be possible to achieve higher improvements.

1 - Performance Analysis in Football

Nowadays the knowledge of the specific performance model has placed at baseline o the training protocol. Coaches, fitness trainer and sports scientist, have to analyses, study and after organizing the new researches, in order to plan the training program in the more specific way. Is important to define that the player's performance model (PPM), is always updated, and that is not the same for every countries, championships, and tournaments. One easy example is that if you are one Jamaican speedrunners, in order to participate at the Olympic Games, your PPM have to follow and be near the national records and not the average of all of the others countries. In order to organize and plan a work plan properly, it is necessary to know the real demands imposed by the competitions of the sport in question and the real skills and qualities of the athlete (D'Ottavio, Tranquilli, 1992)[1]. Therefore the knowledge of the stresses imposed by the competition and the potential quality of the athletes is of extreme importance for the definition of a project useful for the correct administration of specific workloads. The evolution of technology applied to sport and the use of a statistical analytical system for the study of competitions and training has started to create new reference figures, that is, the Match Analyst. Is possible to define the match analysis as the method of data collection that, through the scientific and statistical investigation, allows to evaluate objectively, the physical and technical-tactical performance of the single athlete and the whole team[2]; also according to Sacripanti (2007), the match analysis can represent the keystone that, on the basis of new technologies, can provide the winning card in the hands of the coach and his team.

[1] D'Ottavio S., Tranquilli C., " La prestazione del giocatore di calcio", sds- Scuola dello Sport 1992 Gennaio- Marzo, n.24.

[2] Sacripanti, "La match analisi: fondamenti scientifici e metodologici", SdS/Rivista di cultura sportiva Anno XXVI n.72, 2007

It therefore useful to establish objectively what happens during matches, allowing coaches to optimize the training process[3], especially considering that the best international trainer has a capacity to recall at most 30% of the key factors that determine the success during a single live game[4].

In particular, the match Analyst, also known as a tactical analyst, is a professional with tactical and computer skills that allow him to work with specific computer software for the study of a game; he can be part of the technical staff of a football club and have direct contact with the team or he can be an external collaborator, in support of the technical staff.

The match analysis is therefore crucial especially in the open skill disciplines, such as football and basketball, where the performance does not take place in a simplified and cyclical disciplines but is influenced by several variables due to the presence of the opponents; the succession of events leads to situations that are always different and difficult to assess with the naked eye.

Data collection statistics are used (SCOUTING) in order to break down matches into its most frequent components; this helps the coaches to detect particular events and thus improves the communication between the competition field and the technical staff[5] (Izzo, 2014). The analysis process is not free from practical and technical problems, the main one's concern:

1. Use of complex equipment that involves transport difficulties,

2. The use of these systems provides an exclusively athletic analysis, so the tactical interpretation of the various movements is very subjective,

3. The psychological component of the player is not evaluated,

[3] Bangsbo J., M. Mohr, P. Krustrup, "Physical and metabolic demands of training and match---play in the élite football player. J Sport Sci, Jul 2006;24(7), 665--74,
[4] Franks, I.M. e Miller. G., "Eyewitness testimony in sport". Jopurnal of Sport Behavior, 1986, 9, 39-45
[5] R. Izzo, "Analisi della Performance sportiva: prima parte", Urbino, 2014

4. The high cost of the instrumentation, therefore limited availability only to clubs of from the highest series.

The functions of match analysis can be divided into three main general directions:

a) Main functions referred to Performance:

- Qualitative and quantitative description of events, typical or probable courses of invariant action: competition determinants;

- Identification of the phases and critical actions of the competition;

- Scientific knowledge and evolution of the race-competition system;

- Definition of winning profiles (individual and/or team) and prediction of the optimal outcome: modeling;

- Identification of opposing profiles.

b) Main functions referred to Coach:

- Verify or not the subjective perceptions of the coaches;

- Calculation of individual and team efficiency indices;

- Creation of databases and archives;

- Identification of development objectives for training optimization.

c) Main functions referred to the training model:

- Development of technical strategies and training tactics;

- Individual and team history;

- Physical preparation (estimation of external load) and reconstruction of competition situations during training;

- Psychological preparation;

- Comparison between expectations and the reality of events.

The match analysis allows the coaching staff to analytically partition the objectives of the workouts in three different levels[6]:

- First level training; It is the organization of repeated physical exercise to produce progressively increasing efforts that stimulate the physiological adaptation processes, improving the athlete's technical and physical abilities and enhancing the match performance (Super Compensation).
- Second level training; in this phase the "competition invariants" are identified that characterize the positive performance, studying the technique thanks to the software and the slowed images; therefore aims to the acquisition and improvement of the technical-tactical elements that are reported during matches.
- Third level training; It aims to teach local strategies (that is, in certain areas of the field) and global strategies (game modules in all fields).It is obtained from the tracing of the trajectories. The trainer can manage them to improve their strategies, considering important data that would otherwise be lost.

Figure 1; Phases of Training (Izzo, 2014)

All this has allowed an improvement in the programming of the workouts, which have become more rational thanks to a better physiological knowledge

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[6] Ivi

of the efforts that take place during matches. Workloads are customized based on role, characteristics, and needs. Even the athletic training has benefited, the planned setting now provides an accurate periodization that allows the achievement of certain objectives in the different periods of the year: now they are mainly programmed specific microcycles with precise weekly work, while in the past it tended to organize only megacycles or macrocycles with little consideration of the actual athletic conditions of the players.

1.1 Player Performance Model

The Player Performance Model (PPM) of footballers is composed of numerous components that work together to create sports performance. A sports performance model tends to organize in the simplest and most schematic way all the aspects and elements that together create the performance, in this way it will be easy to assess the level of a single player or an entire team by relating it to reference data obtained through statistical surveys and analyzes. The model describes individual elements that lead to forming a totality that obviously cannot be considered a simple sum of the components[7]. Every modification action towards one or more elements influences all the others, both positively and negatively. It should be noted that the sports performance model is constantly evolving, in particular, that of team sports and in this case even in football.

The model is, therefore, a set of complex interactions between its various components but at the same time, it must be dynamic and adaptable to the various situations and contexts that can be created.

[7] Bangsbo J. "The physiology of soccer—with special reference to intense intermittent exercise." Acta Physiol Scand. 1994;151(suppl 619):1-156.

Football is characterized by an alternating aerobic-anaerobic metabolic commitment with load at the level of muscular engagement that varies between phases of high commitment of short duration and less intense phases. The physical performance is given by the sum of different components that is possible to describe with a very simple formula[8].

Performance = Fitness Status - Fatigue State

The state of Fitness is the set of numerous conditional skills and their subgroups of which important for football we remember: Strength (Functional Strength, Explosive Strength, Strength Resistance, and Speed), Resistance (Aerobics, Anaerobic, and Pcr) and Agility.

The state of fatigue refers to the Doms, Over-reaching, Over-training, Tampering, and de-training. The performance of a player, however, is not only conditioned by conditional factors but also by technical, tactical and mental aspects.

Figure 2; Graphical description of PPM

[8] Giulio S.Roi, "I test di valutazione funzionale nel calcio", Edizioni Correre, 2014;

Through numerous studies and surveys, it was possible to determine the performance model of the elite professional football player.

The average anthropometric characteristics of the player are the following[9]:

- Height (cm): 184 ± 6
- Weight (Kg): 80 ± 5
- BMI (Kg / m2): 23.7 ± 1.0
- Fat (%): 13 ± 3

The average distance traveled per game is about 11 Km, it is obviously influenced by the different roles, the game module, and the tactical settings. Usually, the players who travel more kilometers are the midfielders to follow the attackers and last by the defenders. During a match, a player makes about 1100 changes of activity, for example, from the path to the low-intensity sprint race. It is important to point out that the distance traveled with the ball is about 2% of the total distance.

1.2 The performance of the footballers

In the physiological field, football has always been identified as a high-intensity intermittent sport. Using a classification based on the prevailing or exclusive energy mechanisms involved in the performance model, Dal Monte (1983) places it among the "alternating aerobic-anaerobic" activities, characterized by the alternation of aerobic and anaerobic phases[10]. Bangsbo (2006) states that the aerobic energy production system provides the largest amount of energy used during a meeting, taking into account that a top player maintains an intensity equal to 70% of the maximum oxygen consumption, makes 150-200 actions to high intensity and undergoes depletion ranging from 40 to 90% of muscle

[9] Giulio S.Roi, "I test di valutazione funzionale nel calcio", Edizioni Correre, 2014;
[10] A. Dal Monte, "La valutazione funzionale dell'atleta", Sansoni Ed., Firenze, 1983, p. 165-168

glycogen stores during a game[11]. Both authors then agree that in the determinism of performance, the tactical, technical, coordinative and psychological elements prevail over the energetic ones. The type of work that the player performs is largely made up of short or very short efforts, carried out maximally and repeatedly, alternating with recovery phases that are generally longer. Always Bangsbo (2006) has found that during a match the players make about 1300 variations in the intensity of exercise (metabolic changes)[12]. It has been shown that by increasing the athlete's level of performance and category, his ability to express activity, running or not, at high intensity will be greater. It has long been accepted in the literature that the contribution of aerobic metabolism has a crucial importance in the performance of players: high levels of anaerobic threshold and aerobic power correlate with the coverage in matches of greater distances and with a greater number of sprints also allowing a faster post-match recovery[13] (Ekblom, 1994). During an official 90-minute competition, a player travels a distance between 10 and 13 km, 10-20% of which is high intensity in the form of high-intensity runs or sprints, the remaining quota is traveled at 4/8 km/h (about 25%), light run 8/13(35-40%) and backward run (5%). The overall distance traveled in acceleration and deceleration (> 2.5 m/s^2, < - 2-5 m/s^2) varies between 800 and 1000 meters, with unit distances between 5 and 10 meters[14]. The actions of "tackle", "dribbling", "ball kick", "jump", "header", even if only partially occupying the time of an entire match, have one important weigh on the athlete's workload. Their impact is being quantified in terms of "metabolic load" through algorithms that weigh, data

[11] J.Bangsbo, “Preparazione fisico-atletica del calciatore; allenamento aerobico e anaerobico nel calcio”, Calzetti- Mariucci Ed., Torgiano, 2006, p.11.
[12] Ivi, p.9.
[13] B. Ekblom, “Applie physiology of soccer”, Sports Medicine 3, 1994, p. 50-60.
[14] J.Bangsbo, M. Mohr, P. Krustrup, “Physical and metabolic demands of training and match play in the élite football player”, Journal of sport sciences, 2006, p.665-674.

obtained with GPS or Video Tracking monitoring during training sessions or matches[15].

Another important aspect is that linked to the distance traveled to the various game intensities we take as examples the data obtained from some recent studies on elite players[16]:

- ± 3700m Way (0.2 to 7.2 km/h)
- ± 4400m Low-intensity race (7.3 to 14.4 km/h)
- ± 1800m Run at moderate intensity (14.5 to 19.8 km/h)
- ± 750m High-intensity race (19.9 to 25.2 km/h)
- ± 270m Sprint (> 25.2 km/h)

During game footballers make a sprint every 90 seconds approximately, each of the average duration of 2-4 seconds and that corresponds to 0.5-3% of the total game time. They are in 96% of the cases shorter than 30m and 50% shorter than 10 m[17]. The external effort of footballers will be better investigated in the following chapters.

1.3 The internal effort and physiology of football

In evaluating the energy cost and the metabolic load of football, this task is made difficult by the particularity of the athletic gesture and its heterogeneity due to the different individual requests derived from the role and the variability induced by the tactical component of the game. Starting from the second half of the 80s, heart rate was used as a performance parameter, it was observed that

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[15] M. Sanders, I. Mujika, A. Hewitt, J. Santisteban, R. Bishoff, R. Solano, A. Zubillaga, E. Peltola, P. Krustrup, M. Mohr, " Applications of four different football match analysis: a comparative study", Journal of sport sciences, 2010, p.171-182.

[16] Franco M. Impelizzieri, Ermanno Rampinini, & Samuele M. Marcora, Physiological assessment of aerobic training in soccer, Journal of Sports Sciences, June 2005; 23(6): 583 – 592

[17] Whebe, G. M., Hartwig, T. B., and Duncan, C. S.,"Movement Analysis of Australian National League Soccer Players Using Global Positioning System Technology." J. Strength Cond. Res. 28 (3): 834-42, 2014.

during the 90 minutes it was fairly stable around 80-98% of the f.c. maximum (obtained in the during of a sub-maximal exhaustion test)[18]. The data obtained, considering the relationship between the trend of the heart rate and the consumption of oxygen, have led to the conclusion that the aerobic commitment of football is still high, even if, as considered by Bangsbo (2006), during a match there are factors such as mental stress, dehydration, and hyperthermia which cause the stop of linear relationship between heart rate and oxygen consumption[19].

Considering these factors, it is likely that the aerobic metabolic task during a football match is around 70-80% of the VO2max[20]. These parameters may seem high if compared to the fact that for about half the match, the player walks or run in jogging, or the parameters of average distance/average speed reached (11Km/ 7.2 Km/ h). In reality, these parameters only partially reflect the footballer's activity profile, including as mentioned also high-intensity performance phases. The contribution of the anaerobic alactacid mechanisms (Pcr) in this performance model is considered essential and prevalent[21] (Raven et al, 1976).

However, lactacidemia can vary considerably during match events, with phases whit very high levels of lactate can be found. This and other observations, such as the depletion of muscle glycogen stores from 40 to 90% found at the end of games (Bangsbo et al 2007), show how the glycolytic mechanism of energy production is actually involved[22]. However, the average lactate value detected during competition is not very high (6.6mmol/l during the first half, 4 mmol/l

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[18] B. Ekblom, "Applie physiology of soccer", Sports Medicine 3, 1994, p. 50-60.
[19] J.Bangsbo, M. Mohr, P. Krustrup, "Physical and metabolic demands of training and match play in the élite football player", Journal of sport sciences, 2006, p.665-674.
[20] T. Stolen, K. Chamari, C. Castagna, U. Wisloff, "Physiology of soccer: an update", Sports Medicine, 2005, p.501-536.
[21] PB. Raven, LR. Gettman, ML. Pollock, KH. Cooper, "A physiological evaluation of professional soccer players", British Journal of Sports Medicine, 1976, p. 209-215.
[22] J.Bangsbo, M. Mohr, P. Krustrup, "Physical and metabolic demands of training and match play in the élite football player", Journal of sport sciences, 2006, p.665-674.

during the second half, Bangsbo, 2006), footballers performance seem not be involved with situations of high muscle acidosis[23]. In the final analysis, as regards the contribution of aerobic metabolism in the game of football, it is worth considering that while in the first measurements of many decades ago, football athletes often showed parameters of aerobic potency superimposable to healthy homogeneous sedentary populations by age, today's values, parallel to the athletic evolution of the game of football in the last decades, are lower than what can be observed in resistance athletes, such as cross-country skiers, but with a decidedly different gap[24]. As is reported in the literature, elite footballers show in average a VO2max values between 55 and 65 ml/kg/m, with individual records of 70-75 ml/kg/m[25]. These are relatively modest parameters (lower than at least 10 ml/kg/m) if compared to those found in endurance athletes such as runners, cyclists, cross-country, and skiers, also because football, unlike this type of discipline, does not train aerobic metabolism in such a specific and exclusive way[26]. Some authors argue that there are differences, albeit not significant, in terms of O2 consumption in relation to the position in the field[27]. As in endurance sports, even in football, the anaerobic threshold is considered the best indicator of aerobic performance compared to VO2max[28]. In fact, it is known that specific training is able to produce an increase in the anaerobic threshold even without a corresponding increase in VO2max[29]. Players with the high anaerobic threshold are able to cover, compared to athletes with similar

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[23] Ibid.

[24] AM. Edwards, N. Clark, AM. Macfadyen, “Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged”, Journal of Sports Medicine, 2003, p. 23-29

[25] Ibid.

[26] B. Saltin, PO. Astrand, “Maximal oxigen consumption in atlete”, Journal of Applied Physiology, 1967, p. 353-358.

[27] PB. Raven, LR. Gettman, ML. Pollock, KH. Cooper, “A physiological evaluation of professional soccer players”,
British Journal of Sports Medicine, 1976, p. 209-215.

[28] AM. Edwards, N. Clark, AM. Macfadyen, “Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged”, Journal of Sports Medicine, 2003, p. 23-29.

[29] Ibid.

values of VO2max, but with a lower anaerobic threshold, longer distances and perform higher intensity events, before reaching the lactacid anaerobic phase (lactate> 4 mM/l)[30].

1.4 The External load

“In modern soccer training control and regulation is regarded as a relevant methodological procedure to optimize training adaptations to maximize match performance”[31] (Stølen et al, 2005).

Players progress is the result of the interplay of external and internal loads imposed on players during training sessions. Physiological adaptations are mediated by internal load functional variation, that is influenced by external load effort effectuated during training[32]. The recent exponential advancement of match analysis systems such as multi-camera video tracking and Global Position System Technology (GPS) has enabled the evaluation of player’s external load during specific training and matches in elite and sub-elite soccer. Beside the replicability and accuracy of match analysis hardware have vital importance, such as the validity and reliability of the variables used to describe player’ activities[33]. External training load is usually assessed evaluating distances and time performed in arbitrary selected speed categories.

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[30] AM. Edwards, N. Clark, AM. Macfadyen, *“Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged”,* Journal of Sports Medicine, 2003, p. 23-29

[31] Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of Soccer: An Update. Sports Med. 2005;35:501-536.

[32] Manzi V, Impellizzeri F, Castagna C. “Aerobic fitness ecological validity in elite soccer players: a metabolic power approach.” Journal of strength and conditioning research / National Strength & Conditioning Association. 2014;28:914-919.

[33] Castagna, C., Varley, M., Póvoas, S.C., and D’Ottavio S. 2016. “The Evaluation of the Match External Load in Soccer: Methods Comparison.” International journal of sports physiology and performance September 2016.

“Despite the interest in information obtained through the speed method, if acceleration is not considered the actual nature of soccer-specific training results underestimated.”[34]

In 2010 (Osgnach et al) proposed a new metabolic approach (MP) in order to provide an instantaneous picture of soccer-specific activities[35]. This method considers acceleration and speed to profile individual distances and time spent by players at arbitrary chosen estimated power thresholds. While the MP approach may provide a more detailed tracking of player’ game activity, there is limited research regarding the validity of this method[36] (Buchheit et al, 2015). Thus, information regarding the objective difference and or association of the MP approach over the speed threshold method is unknown[37]. This information has huge practical implications, a growing number of football match analysts are reporting and studying players activity with the MP variables in the attempt to characterize matches and training external-load.

Different studies were trying to investigate the real external effort of professional footballers, not every study was using the same parameters, in this case, the following data are from papers that using the same thresholds[38-39].

The following parameters were taken in consideration:

- Total Distance (meters, D);
- Distance per minutes (meters/minutes, Drel);
- Distance covered at High-Intensity (speed ≥ than 16 km/h, HI);

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[34] Ibid.
[35] Osgnach C, Poser S, Bernardini R, Rinaldo R, di Prampero PE. “Energy cost and metabolic power in elite soccer: a new match analysis approach.” Med Sci Sports Exerc. 2010;42:170-178.
[36] Buchheit M., Manouvrier C., Cassiram J. and Benoit Morin J., “Monitoring Locomotor Load in Soccer: Is Metabolic Power, Powerful?” International Journal of Sports Medicine, September 2015
[37] Castagna, C., Varley, M., Póvoas, S.C., and D’Ottavio S. 2016. “The Evaluation of the Match External Load in Soccer: Methods Comparison.” International journal of sports physiology and performance September 2016.
[38] Ibid.
[39] Osgnach C, Poser S, Bernardini R, Rinaldo R, di Prampero PE. “Energy cost and metabolic power in elite soccer: a new match analysis approach.” Med Sci Sports Exerc. 2010;42:170-178.

- Distance covered at High-Intensity Running (speed ≥18.97 to ≤21.99 km/h, HIR);
- Distance covered at Very High-Intensity Running (speed>21.99 km/h, VHIR);
- Distance covered at High-Metabolic Intensity (MP≥20 watt·kg-1, MPHI);
- Distance at Medium Acceleration > 2 m/s2 (meters, Acc);
- Distance at Medium Deceleration < 3 m/s2 (meters, Dec);
- Distance at Very High Acceleration > 3 m/s2 (meters, HIAcc);
- Distance at Very High Deceleration < 3 m/s2 (meters, HIDec);
- Average Metabolic Power (W/kg, AMP).

Following tables contains data from studies made in professional leagues, table 1 is from Castagna et al (2016), match physical-performance was evaluated in professional top-class players competing during 20 European first-division championships matches (Liga BBVA, Premier League and Bundesliga 1), table 2 shows data from Osgnach et al (2010), that analyzed 56 matches from Italian Serie A. Both studies were carried out using video tracking analysis.

	D	**Drel**	**AMP**	**HI**	**HIR**	**VHIR**	**MPHI**	**Acc**	**Dec**	**HIAcc**	**HIDec**
Average	10672	116	10.6	1778	482	239	2759	636	612	215	209
SD	347	----	0.4	208	67	48	241	118	97	56	48
Min	9417	102	9.1	1156	298	127	2028	397	437	106	120
Max	11595	126	12.0	2310	656	335	3344	911	890	370	380

Table 1; Physical performance data from European Championships (Castagna et al, 2016)

	D	**Drel**	**AMP**	**HI**	**HIR**	**VHIR**	**MPHI**	**Acc**	**Dec**	**HIAcc**	**HIDec**
Average	10950	119	10.7	1996	546	531	2839	591	599	180	188
SD	1044	----	0.5	220	178	214	601	128	130	67	65

Table 2; Physical performance data from Italian Championship (Osgnach et al, 2010).

Footballer travels about 10 km per game, traveled with a range from 9 to 14 km/h, with 1330 change of status, more or less 220 of them carried out at high speed, with variations between first and second half (second half, higher distance traveled at low speed and less sprint)[40]. Considering that in 98% of the time the players are not in possession of the ball, it becomes fundamental to understand when is the best time accelerate and which instead, and which to decrease their energy expenditure[41]. With regard to the various roles, the Central Defenders (CD) are the players who travel less total distance (10.554 Km), less sprint (1.8% of the D), less distance at high intensity > 14 Km/h (2.1% of D) but performing more accelerations and decelerations[42]. The central midfielders (CM) are those who travel the most distance (11,401 km), following several studies[43]. The external midfielders (EM) and the full-back (FB) reach the greatest number of accelerations and sprints compared to other positions[44], even if others researches suggest that forward (FO) have this record (2.6% of sprint compared to D), FO records reach even the highest values in peak velocity[45]. Even if with small differences between the various studies, however, they all say that for each specific role there is a precise physiological demand, coaches must train the different characteristics in a personalized way for each position[46]. The differences in the speed peaks are constant but still modest[47].

[40] Rampinini, E., Coutts, A., Castagna, C., Sassi, R., & Impellizzeri, F., "Variation in top level soccer match performance." International Journal of Sports Medicine, 2007, 28(12), 1018–1024.
[41] Reilly T, Thomas V. "Motion Analysis of Work-Rate in Different Positional Roles in Professional Football Match-Play." J Hum Movement Stud, 1976; 2, 87-97
[42] J. Mallo, E. Mena, F: Nevado, V. Paredes, "Physical Demands of Top-Class Soccer Friendly Matches in Relation to a Playing Position Using Global Positioning System Technology." Journal of Human Kinetics, 2015, 47, 179-188
[43] Vigne, G., Gaudino, C., Rogowski, I., Alloatti, G., & Hautier, C. "Activity profile in Elite Italian Soccer Team." International Journal of Sports Medicine,2010, 31(5), 304–310.
[44] Ibid.
[45] A. Ferro, J. Villacieros, P. Floria, J.L. Graupera, "Analysis of Speed Performance In Soccer by a Playing Position and a Sports Level Using a Laser System" Journal of Human Kinetics, 2014, section 3, 143-153
[46] Ibid.
[47] Ibid.

	Weight (Kg)	Height (m)	D (Km)	D > 24 (Km/h)	D > 21-24 Km/h)	V_{MAX} (Km/h)
CD	77,70	1,81	10.556	1,8 %	2,1 %	27,7
FB	71,38	1,76	10.712	2,4 %	2,4 %	29,2
CM	71,05	1,75	11.401	2,2 %	2,7 %	26,2
EM	71,05	1,75	11.140	2,3 %	2,6 %	29,3
FO	71,71	1,79	10.759	2,6 %	2,7 %	29,3

Table 3; Anthropometrical and Physical data from different roles (Ferro et al, 2014).

To try to have the most global and prospective vision possible, is possible to analyze, the variations of parameters using different tactic modules: each module provides a different physiological request.

Among the most relevant results is possible to note that:

- 3-5-2 is the most expensive module as regards D, HSR, and MPHI;
- 4-2-3-1 is the module that required more acceleration and deceleration for the entire team;
- FO of 3-5-2 perform more of 45% distance in HSR than 4-2-3-1;
- In 4-3-3 FO perform more of 50% acceleration and deceleration than 4-2-3-1.

Observing these data, we understand once again how the physiological demands of the players must be trained in a personalized way, taking into account the different variables (role, age, physical structure, etc.).

2 State of Art

The sports performance of footballers during games and training has been the subject of research for years. Nowadays there is an increasing number of football analyst that organize the variables detected with different and various methods.

Reilly and Thomas (1976) who described a football competition counting the number of steps taken for each movement performed by the players (walking, running and shooting) took one of the pioneering studies[48]. From that starting point, the match analysis has undergone significant changes, through the notational analysis (notational analysis, which can be manual or computerized), motion analysis (which analyzes the activity and movements of athletes) and video analysis (it is practically realized with the installation of automated systems inside the stadiums)[49]. Thanks this new technology during years were executed some studies, that took into consideration the distances traveled and the movements of the players in the field (Rienzi et al, 2000, Ohashi et al, 2002, Mohr et al, 2003, Figueroa et al., 2004, Rampinini et al., 2007 and Di Salvo et al, 2009).

In 2010 (Osgnach at al.) was proposed a new method to analyze the PPM during matches and training, this was a turning point the evolution of performance analysis. The new method analysis was based on the evaluation of training load using the metabolic power (MP), mediating changes in speed activities and acceleration of the individual athlete. Subsequently numerous studies were performed through GPS technology and semi-automatic video tracking system, trying to evaluate, accelerations, decelerations, changes in speed and relative

[48] Reilly T., Thomas V., “A motion analysis of work-rate in different positional roles in professional football match-play”, J Hum Mov Stud, 2 : 87 – 97, 1976.
[49] Tibaudi A., “La Match Analysis applicata al calcio”, Scienza & Sport num. 24, 2014.

energy expenditure (D'Urbano et al., 2010, Akenhead et al., 2012, Guadino et al., 2013, Keiner et al., 2014, Black et al., 2015, Dalen et al., 2016).

Subsequently, the state of the art of the individual hardware taken into account in the development of the thesis will be described in detail.

2.1 Global Position System

The Global Position System (GPS) is a system that processes position signals, sent from satellites in orbit, providing position and time to a GPS receiver.

Calculates the position in the 3 axes, x, y, and z is possible to calculate the coordinates thanks to the trilateration process; the hardware is composed by:

- Space segment: consisting of 31 satellites;

- Control segment: composed of several control stations and antennas;

- User segment: it is the GPS receiver; it is based on the spherical positioning method, which consists in measuring the time taken by a radio signal in traveling the satellite-receiver distance (the signal must be received by at least 4 satellites).

The GPS can be used in a static or kinematic to measure the movement of the players and then quantify the level of physical effort. The accuracy of the detection depends on weather conditions, satellite position, and type of receivers and radio propagation effects of the radio signal[50]. In recent years the sports world has been interested in GPS to evaluate the physical parameters of athletes; with GPS you can analyze the athlete's actions and movements thanks to satellite triangulation, thus allowing to measure different parameters[51].

[50] R. Izzo, “Analisi della Performance sportiva: seconda parte” Urbino, 2014
[51] R. Izzo, “Analysis of significance of physical parameters in football through GPS detection in a comparison with amateur athlete”, Research gate, December 2015

GPS can have different frequencies: 5, 10, 25 and 50 Hz (a higher sampling frequency allows greater measurement validity). Their accuracy is influenced by several variables, but it has been shown that the latest 10 Hz GPS is quite reliable in calculating accelerations, decelerations, and distance covered during the various stages of games in team sports, while those at 5 Hz are less reliable[52].

In general, GPS is reliable in assessing the external load of training[53], even if they tend to overestimate the distances during curvilinear changes of direction and underestimate them during the shuttle tests[54], so their accuracy decreases in high-intensity actions and changes of direction[55].

The 10 Hz GPS is more reliable than the 15 Hz[56], although the 15Hz is more accurate in evaluating the maximum speed peaks, while the 10 Hz one more accurately detects the total distance (error: <1 %), average speeds and duration times of actions. However, both devices are limited in evaluating speeds exceeding 20 km/h (error: from 0.8 to 19.9%); 1 and 5 Hz GPS is less reliable in measuring total distance (error: <7.2%), speaking speed (error: 10%), and speeds exceeding 20 km/h (error from 17 to 30%)[57].

Reliability can also be negatively influenced by sudden changes of direction during the competition, fast speed variations and also by the presence of high

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[52] Varley MC, FI H, Aughey RJ. "Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion." J Sports Sci 2012; 30, 121–127

[53] Vickery WM, Dascombe BJ, Baker JD, Higham DG, Spratford WA, Duffield R. "Accuracy and reliability of GPS devices for measurement of sports-specific movement patterns related to cricket, tennis, and field-based team sports." J Strength Cond Res, 2014; 28, 1697-1705

[54] Rawstorn JC, Maddison R, Ali A, Foskett A, Gant N. "Rapid directional change degrades GPS distance measurement validity during intermittent intensity running." PLoS One, 2014; 9, e93693

[55] Jennings D, Cormack S, Coutts AJ, Boyd L, Aughey RJ. "The validity and reliability of GPS units for measuring distance in team sport specific running patterns." Int J Sports Physiol Perform, 2010; 5, 328-341

[56] Johnston RJ, Watsford ML, Kelly SJ, Pine MJ, Spurrs RW. Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. J Strength Cond Res, 2014; 28, 1649-165

[57] Ivi.

walls or with the presence of a roof full coverage, that significantly reduces GPS satellite detection[58] (Jeggins, et al., 2011).

Rampini (2015) compared a device at 10 Hz and one at 5 Hz, noting that the 5 Hz has a low error (2.8%) in calculating the total distance and the medium-low thresholds of metabolic power (4.5%) while the error increases with increasing metabolic power (from 7 to 23%); the 10 Hz GPS has a negligible error on the total distance (1.9%), medium-low metabolic power (2.4%) while increasing with the high metabolic powers (4-10%). He concludes that both evaluate the total distance well, but not the parameters concerning the high intensities, moreover the difference in error between the two devices varies between 30 and 50%[59].

Type	Total Distance	Speed Peak	Velocity > 20 Km/h	MP (>25 W/Kg)
1 e 5 Hz	< 7,2 %	10 %	17 – 30 %	7 – 23 %
10 Hz	1-1,9 %	1,6 %	0,8 – 19,9 %	4 – 10 %
15 Hz	2 %	< 1%	0,8 – 19,9 %	/

Table 4; GPS Error Percentage (Castellano et al., 2011, Johnston et al., 2014, Rampinini et al., 2015)

Is important to notice that all of this data and percentage are straightly influenced from specific hardware to specific hardware, this means that different companies (K-Sport, Catapult. Stats-Sport, Colli, Gpexe etc...) can have different merits and defects, and that the previous studies were carried out not with all products present on market.

2.2 Video Tracking System

The Video analysis is carried out with the installation of cameras devices that allow to filming matches after data are analyzed thanks to specific tracking software. Can be used to study and evaluate the athlete's body movements, the

[58] Castellano J., Casamichana D., Calleja-González J., San Román J. and Ostojic S.M. "Reliability and Accuracy of 10 Hz GPS Devices for Short-Distance Exercise" J Sports Sci Med. 2011 Mar; 10(1): 233–234.

[59] Rampinini E, Alberti G, Fiorenza M, Riggio M, Sassi R, Borges TO, Coutts AJ. Accuracy of GPS Devices for Measuring High-intensity Running in Field-based Team Sports. Int J Sports Med, 2015; 36, 49-53

team's tactical evolutions and even the external effort, allowing detecting reliable feedback thanks to the fact that the athlete is analyzed in a moment of true expression of the gesture, without the feeling of tension of a test or from wearing one uncomfortable hardware. These video tracking systems are an important tool for identifying players' physical efforts during the various competitions, with a low error rate, which stands at 1.8%[60].

A network of cameras placed around the field, which allow a wide and precise shooting over the entire game space, characterizes this technology; movies are uploaded to a computer that is able to identify and track players during the matches, the system can be manual, semi-automatic or completely automatic. Only elite sports clubs can take advantage of this technology because of the very high costs[61].

Initially, the video analysis concerned a single athlete, although it happened with high-efficiency standards, could be influenced by possible human errors in the codification and manual interpretation of a certain athletic gesture. To solve this situation, the "Time-Motion Analysis" entered the scenes and, relying on mathematical models for automatic tracking, allows the description of the most important events in the right sequence in real time.

After the succession of various techniques nowadays is possible monitoring multiple players, one example is the software “Amisco Pro", which allows a video measurement of all the subjects moving within the field of play, used for basketball, rugby and basketball.

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[60] Redwood-Brown A, Cranton W, Sunderland C. Validation of a real-time video analysis system for soccer. Int J Sports Med. 2012; 33, 635–40

[61] Marcolini M.,”La match analisi: un nuovo approccio scientifico”; Urbino, 5° Convegno sul calcio giovanile: “Prima del risultato”, 2010

The disadvantage of this technology, in addition to cost, is the need for an operator who organizes the captions and after the collection of the large amounts of data obtained[62].

Nowadays, despite the development of other software and the high level of automatic detection, the manufacturing companies cannot give certification of complete reliability, due to ambiguous situations in which the simultaneous presence of multiple players occurs in a small portion of the field, condition that causes confusion both to automatic tracking and to the manual operator.

The video analysis takes place in 4 phases:

1) Observation: this is the phase in which data are detected with static or dynamic cameras, which allow the acquisition of video sequences and thus provide detailed information on individual and collective race behavior;

2) Preparation: the processing of information collected thanks to video recordings (scouting);

3) Application: use of the data processing results to adapt the technical-tactical strategies (delivery of the report);

4) Transformation of the results in parameters to be trained: it is the optimization of the useful work to get more prepared for future matches.

Is possible to predict how video analysis can achieve excellent levels of precision, but coaches need to focus our attention more on data quality (through integration with other technologies) than on quantity, in order to avoid the data mining[63].

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[62] Di Salvo V, Collins A, McNeill B, et al. Validation of Prozone: A new video-based performance analysis system. Int J Perf Anal Sport 2006 Jun; 6 (1), 108-119

[63] J. Castellano, D. P. Alvarez, Paul S. Bradley, "Evaluation of Research Using Computerised Tracking Systems (Amisco and Prozone) to Analyse Physical Performance in Elite Soccer: A Systematic Review, Sports Med (2014) 44, 701–712

2.2.1 Comparing GPS and Video Tracking System

Video tracking systems with multiple cameras tend to overestimate the distance covered at high intensity (> 18 Km/h) compared to GPS[64]; video analysis also slightly overestimates the distances covered at various speeds, overestimates the peak of maximum speed and the average speed, but calculates better the total distances[65], even if we must consider that often the cameras cannot be installed in optimal locations.

GPS are more accurate in measuring accelerations[66], but tend to underestimate the distances covered (error: 1-3%)[67], are more accurate in calculating linear actions than changes in direction[68], underestimate the average speed of about 6% and sprints also tend to decrease in precision with increasing distance[69].

Some studies state that GPS is the most efficient technology for recording and managing data[70] (Buchheit at al., 2014).

Both systems are reliable in measuring the total distance, the peak of maximum speed and the distances greater than 30 meters, while they tend to drop precision

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[64] Harley, J. A., Lovell, R. J., Barnes, C. A., Portas, M. D., & Weston, M. The interchangeability of global positioning system and semiautomated video-based performance data during elite soccer match play. Journal of Strength and Conditioning Research, 2011, 25, 2334–2336.

[65] Randers, M., Mujika, I., Hewitt, A., Santisteban, J., Bischoff, R., Solano, R., Mohr, M. Application of four different football match analysis systems: A comparative study. Journal of Sports Sciences, 2010, 28, 171–182.

[66] M. Beato, D. Bartolini, G. Ghia, P. Zamparo, "Accuracy of a 10 Hz GPS Unit in Measuring Shuttle Velocity Performed at Different Speeds and Distances (5 – 20 M)", Journal of human Kinetics, 2016, 54, DOI: 10.1515/hukin-2016-0031

[67] M. Buchheit, A. Allen, T. Poon, M. Modonutti, W. Gregson & V. Di Salvo, Integrating different tracking systems in football: multiple camera semi-automatic system, local position measurement and GPS technologies, Journal of Sports Sciences, 2014, Vol. 32, No. 20, 1844–1857

[68] Petersen, C., Pyne, D., Portus, M., & Dawson, B. Validity and reliability of GPS units to monitor cricket-specific movement patterns. International Journal of Sports Physiology and Performance, 2009, 4, 381–393.

[69] Vickery, W. M., Dascombe, B. J., Baker, J. D., Higham, D. G., Spratford, W. A., & Duffield, R. Accuracy and reliability of GPS devices for measurement of sportsspecific movement patterns related to cricket, tennis and field-based team sports. Journal of Strength and Conditioning Research, 2014, 28, 1697–1705.

[70] M. Buchheit, A. Allen, T. Poon, M. Modonutti, W. Gregson & V. Di Salvo, Integrating different tracking systems in football: multiple camera semi-automatic system, local position measurement and GPS technologies, Journal of Sports Sciences, 2014, Vol. 32, No. 20, 1844–1857

with short distances, short sprints and changes of direction (the last parameter is more penalized in GPS)[71].

In addition to technical applications we must consider the practicality of use of the two systems, their effective application in official competitions: GPS can be used during matches and trainings, but a large number of players don't like to wear GPS jacket during official events, a very limiting condition for the purpose of a true contextualization of the data collected.

Video analysis, on the other hand, is applied during official competitions and, besides inhibiting the psychological aspect of an evaluation, has the advantage of providing a lot of data (both athletic and technical-tactical) much greater than GPS, although it can there is the personal interpretation of the operator who performs it. Neither system can, therefore, prevail over the other, as both have shown greater and lesser validity in different situations[72].

2.3 Breathing Analysis and Metabolimeter

Metabolimetry is the study of the metabolic status of a subject, through the measurement of gaseous exchanges. It can be performed both in conditions of rest and effort: in the first case it allows us to evaluate the basal calorie consumption of the individual, in the second we show the metabolic response of the same to a determined stimulus. Is possible to find a several numbers of metabolimeters on market, we will focus in special in the analysis of the portable system, Cosmed K4 b2 (Cosmed, Italy), because is the most used in sports ambit and researches[73].

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71 Ivi.

72 Ballesta Castells, C.; García Romero, J.; Fernández García, J.C. y Alvero Cruz, J.R, Current methods of Soccer Match Analysis, Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 2015, vol. 15 (60) pp. 785-803

73 Naughton L.R., Sherman R., Roberts S., Bentley D.J. "Portable gas analyser Cosmed K4b2 compared to a laboratory based mass spectrometer system." J Sports Med Phys Fitness 45: 315–323, 2005.

The metabolimeter, measure gaseous exchanges, that are: Ventilation (VE) in liter of air/minute, respiration rate, Consumption of O2 (V'O2, difference between concentration of O2 exhaled, with ambient air: range 21- 15%), CO2 production (V'CO2, as above: range 0-5%).

These parameters and those derived from them, together with the relief of the heart rate response, allow the accurate study of metabolic status during any type of stimulation or test. In particular, during a maximal incremental test, it is possible to evaluate the aerobic component, the "equilibrium" phase, and the anaerobic component. The result is, therefore, the possibility to define accurately: prevalence or less of the aerobic phase compared to the anaerobic phase; the point of passage (threshold) in terms not only mechanical but from the metabolic status during the anaerobic phase until exhaustion.

Football is an alternate aerobic/anaerobic sport, where maximum sprints are performed, changes in direction, elevation, contrasts, with more or less short recovery phases. The performance consists of the athletic point of view in the ability to repeat many times seems gestures without drops in intensity.

The metabolic study of a maximal incremental effort, although not specific to the functional model of soccer, allows having fundamental information for defining the metabolic "type", identifying the thresholds of the aerobic phase, measuring the maximum aerobic power and the related mechanical parameters, study status during the anaerobic phase until exhaustion.

In fact, it is necessary to consider that, in a sport where determinants are agility, technique, reading of situations, psychological and character conditions, the elite have very different subjects from the point of view of athletic qualities and characteristics, both constitutional and developed. . It is therefore important to know the athletic type of each team member, an essential condition to propose truly personalized stimuli.

The cardiopulmonary exercise test, by studying the functional response of the heart-lung pair, ensures a precise, reproducible and objective measurement of the subject's ability to perform physical exercise. The principle, on which the cardiopulmonary exercise test is based, is the indirect calorimetry. Based on the measurement of the expired air volume and the analysis of gaseous composition, in relation to the amount of work performed and to the modifications that the exercise determines to heart rate frequency and arterial pressure, it is possible to follow the trend of the oxidation processes from the resting phase up to the maximal exercise.

Main concept:

• In the face of the same test and of an identical protocol, the metabolic behavior, regardless of the result in mechanical terms, varies according to the individual characteristics, mostly constitutional/genetic;

• It is however necessary that every high-level player, given the current intensity conditions of the matches and of their frequency, reaches a level of aerobic power sufficient to guarantee an optimal recovery, both "in acute" (during the match) that "in post-acute" (in the following hours); to preserve performance and prevent injuries and over-training;

Trying to simplifying, is possible to distinguish an "aerobic" behavior (usually high levels of VO2max, VO2AT, progression curves of VO2-VCO2 with a clear prevalence of the RR phase < 1, short phase after the switch, the modest differential between maximum consumption of O2 and maximum production of CO2). At the opposite extreme, the "anaerobic" behavior, with relatively low-medium values of VO2max and VO2AT, the prevailing phase at RR> 1, the high differential between VO2max and maximum production of CO2. In the middle, a "balanced" behavior, with obviously intermediate characters. Testing a football team, usually, all three types are detected, with a non-absolute correlation with the roles covered in the field.

Main parameters evaluated from Metabolimeter are:

- VO2: represents the amount of oxygen taken from the lungs, transported to the tissues and used to work. It is largely determined by hereditary factors, but aerobic training can increase it up to 35%; can be considered as a predictor of a person's ability to practice aerobic exercise[74];
- Heart rate: Heart rate means the number of heartbeats (or pulsations) that the heart makes in one minute (bpm). During physical activity, the heart rate rises in relation to the increase in the intensity of activities[75];
- VO2max: represents the maximal amount of O2 that the organism can take from the air through the ventilator function, transport through the cardiovascular system and use at the level of the muscles in the unit of time. During the execution of an effort, the consumption of O2 increases linearly with the load up to a limit value defined precisely VO2 maximum. According to the Fick[76] equation (VO2 = Gs x FC x d A-V of O2), the VO2 max, therefore, represents the moment in which the cardiac output and the arterio-venous difference have reached the maximum values. In physiological conditions, the difference A-V do O2 is a constant fraction, which has a constant linear increase based on the amount of work performed and is independent of variables such as sex and age. The VO2max is therefore only a function of maximum cardiac output. In practical terms, the VO2max is identified from the moment when, at the peak of the effort, the VO2 settles into a plateau phase despite a further increase in the workload;
- VAM (maximum aerobic velocity): is intended as the running velocity corresponding to the beginning of the plateau phase of the oxygen

[74] K. Patton e Thibodeau, "Anatomia e fisiologia", Elvesier, 2011
[75] J. Bangsbo, "Preparazione fisico atletica del calciatore, allenamento aerobico e anaerobico nel calcio", Torgiano: Calzetti-Mariucci, 2006
[76] Adolf F., "Ueber die Messung dea Blutquantums in den Herzventrikela". Verhandlungen der Physikalisch-medizinische Gesellschaft zu Würzburg (in German) 1870. 2: XVI–XVII. Retrieved 24 Oct 2017.

consumption curve. The VAM is identified at the beginning of the VO2max plateau. The values of VAM are lower than those measured by indirect methods, those of anaerobic threshold have different correlations depending on the tests used, and the sub-maximal thresholds are not detectable indirectly;

- Anaerobic threshold is the maximum level of physical exertion that the body can sustain without accumulating lactate in the blood. It then indicates a level of heart rate and power beyond which the lactate product becomes more than the one disposed of. Below this threshold, the athlete's effort is mainly supported by aerobic exergonic systems and can be sustained for long periods. Above the threshold, on the other hand, anaerobic exergonic systems are activated, whit an accumulation of lactate. Hyperlactatemia is buffered by the bicarbonate system producing non-metabolic CO2 that reverses the VCO2/VO2 ratio (respiratory quotient). The anaerobic threshold (AT) can be determined by evaluating the V-slope, the function described by the VCO2/VO2 ratio. In the first part of the effort, the relationship remains constant; when the production of non-metabolic CO2 begins, the first straight curve undergoes a deviation upwards: the inflection point represents the AT[77].

Following data from some studies one VO2max that tray to compare professional with amateur footballers.

VO2 Max

Studies	Élite	Amateur
Wells et al. (2012)	56,5 ± 2,9	55,7 ± 3,5
Haugen et al. (2015)	62 ± 2	± 61
Rampini et al. (2009)	58,5 ± 4	56,3 ± 4,5
Yanci et al. (2015)	/	54

Table 5; Comparison between Elitè and Amateur football players

[77] K. Wasserman, “Principles of exercise testing and interpretation”, Lea & Fabiger Ed, 1994, p. 62-64.

Studies show that in term of VO2Max, is not possible define big differences between Elite and Amateur football players, this means that is not this parameter that defines quality in the team, sport such as football[78].

2.4 Metabolic Power

Early assessments of metabolic demand, which were conducted through measurements of body temperature, demonstrated that the average metabolic load of a soccer player is close to 70% of V˙O2max[79]. More recently, assessments of energy expenditure have been performed using continuous HR recording, allowing a detailed analysis of aerobic performance[80], but this kind of approach is not allowed during official matches. In addition, HR recordings do not yield information on high-intensity movements. Likewise, direct measurement of oxygen uptake is not suitable to provide data on high-intensity exercise, and its use during training sessions or competitions is impossible[81]. Studies show that the total estimated energy expenditure during a match swing from 1200 to 1500 kcal[82].

The studies conducted so far on anaerobic energy expenditure are rather scant; furthermore, the current procedures are not applicable to official matches and are definitely not suitable for continuous recordings. An example of this

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[78] Rampini, A. Sassi, Repeated-sprint ability in professional and amateur soccer players, Appl. Physiol. Nutr. Metab.,2009, 34, 1048–1054, doi:10.1139/H09-111

[79] Edwards A.M., Clark N.A., “Thermoregulation observations in soccer match-play: professional and recreational level applications using an intestinal pill system to measure temperature.” Br J Sports Med. 2006;40(2):133–8

[80] Esposito F., Impellizzeri F.M., Margonato V., Vanni R., Pizzini G., Veicsteinas A., “Validity of heart rate as an indicator of aerobic demand during soccer activities in amateur soccer players.” Eur J Appl Physiol. 2004;93(1–2):167–72.

[81] Kawakami Y., Nozaki D., Matsuo A. and Fukunaga T., “Reliability of measurement of oxygen uptake by a portable telemetric system.” Eur J Appl Physiol. 1992;65(5):409–14.

[82] Van Gool D., Gerven D., and Boutmans J., “The physiological load imposed in soccer players during real match-play.” In: Reilly T, Lees A, Davids K, et al.., editors. Science and Football. London (United Kingdom): E & FN Spon; 1988. p. 51–9.

approach is the study by Krustrup et al. (2006)[83], which measured creatine phosphate concentration on biopsies taken from muscular tissue of athletes immediately after high-intensity exercise actions during a soccer match. Blood lactate concentration (LA) has also been considered as a marker of anaerobic energy expenditure by several researchers; the results of these studies show that its level during matches ranges from 2 to 10 mM/l[84].

The methods described above are sufficiently reliable in estimating the total energy expenditure during a match. However, no method is currently available to measure or estimate instantaneous metabolic load, and this is particularly true in relation to high-intensity actions, which are actually the crucial moments in matches.

During the last few years, an increasing number of studies have been devoted to video analysis of soccer matches and to the subsequent computer-assisted analysis of performance, this leads to a significant progress in the physical assessments of individual players and is currently being used by many high-level professional soccer teams all over Europe. The most update techniques of video match analysis allow close observation of the movements of players, referees, and ball on the soccer pitch throughout the 90 min of the game. Results of these studies were analyzed previously.

However such analyses do not take into account an essential element of soccer, accelerations, decelerations, and changes in running activities. It his a fact, that a massive metabolic load is imposed on players not only during the maximally intensive phases of the match (high running speed) but every time acceleration is elevated, even when speed is low.

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[83] Krustrup P., Mohr M., Steensberg A., Bencke J., Kj&r M., and Bangsbo J., “Muscle and blood metabolites during a soccer game: implica- tions for sprint performance.” Med Sci Sports Exerc. 2006;38(6): 1165–74.
[84] Ibid.

The scientific literature provides a significant number of studies on the energetics and biomechanics of constant speed running, although the number of studies on accelerated (or decelerated) running is not many, because of the difficulty in using an energy approach in evaluating this exercises.

The few works available on the subject focus exclusively on specific mechanical features of sprinting or consider indirect estimates of its energetics.

In 2010 (Osgnach et al.) propose a new analytic approach to football performance introducing the concept of Metabolic Power[85], using a theoretical model introduce from Di Prampero.

2.4.1 Theoretical Model

The purpose of this section is to describe briefly the approach proposed by di Prampero et al. (2005) in estimating the energy cost (EC) of accelerated and decelerated running.

Di Prampero et al. (2005) have shown that, as a first approximation, accelerated running on a flat terrain is energetically equivalent to uphill running at constant speed[86]. During sprints, the runner's body leans forward forming an angle with the terrain, which is smaller, when the acceleration is greater.

If the terrain is tilted upward to bring the runner's body vertical (Fig. 1), accelerated running can be considered equivalent to running at a constant speed up an equivalent slope (ES) = $\tan(90 - \alpha)$.

In Figure 1 runner's body is represented by a segment of a straight line: COM, the center of mass; T, terrain; H, horizontal; g, acceleration of gravity; af,

[85] Osgnach C., Poser S., Bernardini R., Rinaldo R. and Di prampero P.E, "Energy Cost and Metabolic Power in Elite Soccer: A New Match Analysis Approach" Medicine and science in sports and exercise · January 2010

[86] Di Prampero PE, Fusi S, Sepulcri L, Morin JB, Belli A, Antonutto G. "Sprint running: a new energetic approach." J Exp Biol. 2005; 208(Pt 14):2809–16.

forward acceleration; g', vectorial sum of af and g. Accelerated running on flat terrain (A) is equivalent to constant speed uphill running (B).

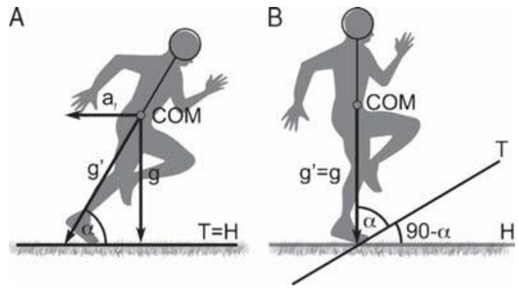

Fig 3; Simplified view of the forces acting on a subject during accelerated running (Di Prampero et al., 2005)

In addition, the average force exerted by the active muscles during sprinting is greater than the subject's body weight by the ratio g'/g. This ratio is called ''equivalent mass'' (EM) and represents an overload imposed on the athlete by the acceleration itself.

$$EM = g'/g$$

Therefore, if the forward acceleration is known, ES and EM can be easily determined. According to Minetti et al. (22), the energy cost (EC, $J \times kg^{-1} \times m^{-1}$) of running uphill at constant speed is described by[87]:

$$EC = 155.4i^5 – 30.4i^4 – 43.3i^3 + 46.3i^2 + 19.5i + 3.6$$

Where i is the incline of the terrain, and 3.6 ($J \times kg^{-1} \times m^{-1}$) is the EC of running at constant speed on flat compact terrain; therefore, the EC of accelerated running can be easily obtained with the following equation, where i has been replaced by ES, and the overall cost is multiplied by EM.

$$EC = (155.4ES^5 – 30,4ES^4 – 43.3ES^3 + 46.3ES^2 + 19.5ES + 3.6) \times EM$$

[87] Minetti A, Moia C, Roi GS, Susta D, Ferretti G. "Energy cost of walking and running at an extreme uphill and downhill slopes." J Appl Physiol. 2002;93(3):1039–46.

Metabolic power (P) can be then calculated multiplying EC by running speed (v):

$$MP = EC \times v$$

Therefore, once speed and acceleration are known, the metabolic power output of each athlete in every analyzed movement can be easily obtained and will be evaluated as W/kg, the described analysis allowed estimating EC and metabolic power.

Osgnach et al. (2010) thanks to this theoretical approach introduced new parameters in order to analyze the PPM in a more specific way, following the list:

- Equivalent distance (ED): This represents the distance that the athlete would have run at a steady pace on grass using the total energy spent over the match. Data provided by Minetti et al. (2002) and considered by di Prampero et al. (2005) refer to running on a treadmill, for this reason, the values of EC were multiplied by a constant (KT = 1.29) to take into account the fact that running on a football field is approximately 30% more harder than running on compact homogeneous terrain[88];
- Equivalent distance index (%ED): This represents the ratio between ED and TD in the period considered;
- Anaerobic index (%AI): This represents the ratio between the energy expenditure above a certain metabolic power threshold selected by the investigator (corresponding to VO2max or to anaerobic threshold) and the total energy expenditure over the whole match in the considered period;
- VO2: Is the estimated value of VO2 consumed during the considered period.

[88] Pinnington HC, Dawson B., "The energy cost of running on grass compared to soft dry beach sand." J Sci Med Sport. 2001;4(4): 416–30.

2.5 Limit of Metabolic Power Model

The model proposed by Di Prampero (2005) and later reworked by Osgnach (2010), although it has found numerous successes in the analysis of sports performance, especially from Italian's sports scientists, has numerous limitations and inaccuracies.

As stated by the authors themselves (Osgnach et al., 2010):

1. The overall mass of the runner is assumed to be located at the center of mass of the body. As such, any possible effects of the motion of the limbs on the energetics of running were neglected. This is tantamount to assume that the energy expenditure associated with internal work is the same during uphill running as during sprint running at an equal ES. This is probably not entirely correct because the frequency of motion is larger during sprint than during uphill running. If this is the case, the values obtained in this study represent a minimal value of the EC or metabolic power during the match[89].

2. For inclines greater than +0.45, there are no data on the EC of uphill running. In this study, we did not observe acceleration greater than 5 ms^2, corresponding to ES = +0.50[90].

During the last few years, some studies were trying to investigate the efficiency of the MP method, using different analysis protocol.

Stevens et al. (2014) were trying to investigate the additional energy cost of 180° changes of direction during aerobic continuous (10 m) shuttle running compared to constant running. It was hypothesized that the energy cost of shuttle running is higher than for constant running at the same average speed and that the difference between constant and shuttle running increases with

[89] Osgnach C., Poser S., Bernardini R., Rinaldo R. and Di prampero P.E, "Energy Cost and Metabolic Power in Elite Soccer: A New Match Analysis Approach" Medicine and science in sports and exercise · January 2010

[90] Ibid.

speed. Because in practice direct measurement of energy cost is not feasible, the study second aim was to compare the estimation of energy expenditure by di Prampero's approach using time–motion data collected using video tracking system (500Kz resampled at 10Hz) to measured energy expenditure assessed from breath-by-breath (K4b2; Cosmed Slr, Rome, Italy) respiration during both constant and shuttle running. The experimental protocol consisted of two sessions, separated by at least 30 min. In the first session, participants performed 10m continuous shuttle runs, starting with an average speed of 7.5 km/h. Speed was increased by 0.5 km/h every 3 min until the last stage of running was 10 km/h. In the second session, participants followed the same protocol for constant running (without abrupt changes of direction), immediately followed by an incremental protocol (an increase of 1.0 km/h each minute) until exhaustion to determine maximal oxygen consumption (VO2max). Constant running was performed on a 160m track marked with cones; shuttle running turning lines were marked with two cones (1 m width). Running speed was paced by an audio signal; participants had to be at the next cone (constant run) or on the line (shuttle run) at the beep. In this way, average speed at each stage would be similar between runs. During the shuttle runs, participants had to alternate turning foot and turned with at least one foot on the line.

Results show that for shuttle running, estimated energy cost was significantly lower (13% to 16%) than measured energy cost with K4 and for constant running, estimated energy cost was significantly higher (6%–11%) than measured with golden standard, is important to notice that this test was performed in amateur football players.

Another important study comparisons one MP was built by Buchheit et al. (2015) they start from the assumption that the study of Stevens (2014) may not be representative enough of soccer practice[91]. Because players did not have to

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[91] Buchheit M., Manouvrier C, Cassiram J. and Morin J.B, "Monitoring Locomotor Load in Soccer: Is Metabolic Power, Powerful?" International Journal of Sports Medicine · September 2015

pass the ball or shot, and the protocol didn't include rest periods, but the comparisons were performed during shuttle runs and continue running. The aim of the study was, therefore, to examine, in highly-trained young soccer players, the validity and reliability of the estimation of metabolic power (MP) from locomotor demands during soccer-specific drills with the ball.

The players performed a soccer-specific circuit with the ball at two different occasions within two weeks, at the same time of the day. The players were well familiar with the circuit, which they had all already performed at least twice the month preceding the experimentation. To avoid the large variability of the locomotor responses to typical small-sided games, which may be problematic to assess the actual reliability of comparison, they decided to simplified analysis with a soccer-specific circuit with the ball, since soccer is an intermittent sport, some rest periods were also introduced between the circuit repetitions.

This circuit included slaloms with the ball, to pass and receive of a rebound wall and shot on goal. After a standardized 10 minutes warm-up without the ball, the players completed the soccer-specific circuit for 2 minutes as a trial. The players adjusted their running speed according to auditory signals timed to match the 19m intervals delineated by the two external lines. After a 1 minute recovery period, players started the experimental protocol and performed again the circuit at speeds of 6.5, 7 and 7.5 km/h (with the exercise bouts interspersed with a 30 seconds passive recovery period). Locomotor activity was monitored during each session with 4-Hz GPS units (VX, VX340a, Lower Hutt, New Zealand), while oxygen uptake (VO2) was repeatedly collected with the same portable gas analyzer (MetaMax 3B, Cortex-Biophysik, Leipzig, Germany).

Results shows that the MP method tended to very largely underestimate the actual net metabolic demands (assessed via indirect calorimetry, PVO2), especially during the resting phases (that was 0 during resting phases for GPS measurement) and there was only a small correlation between locomotor-related metabolic power and actual net metabolic demands, with a moderate typical error of the estimate.

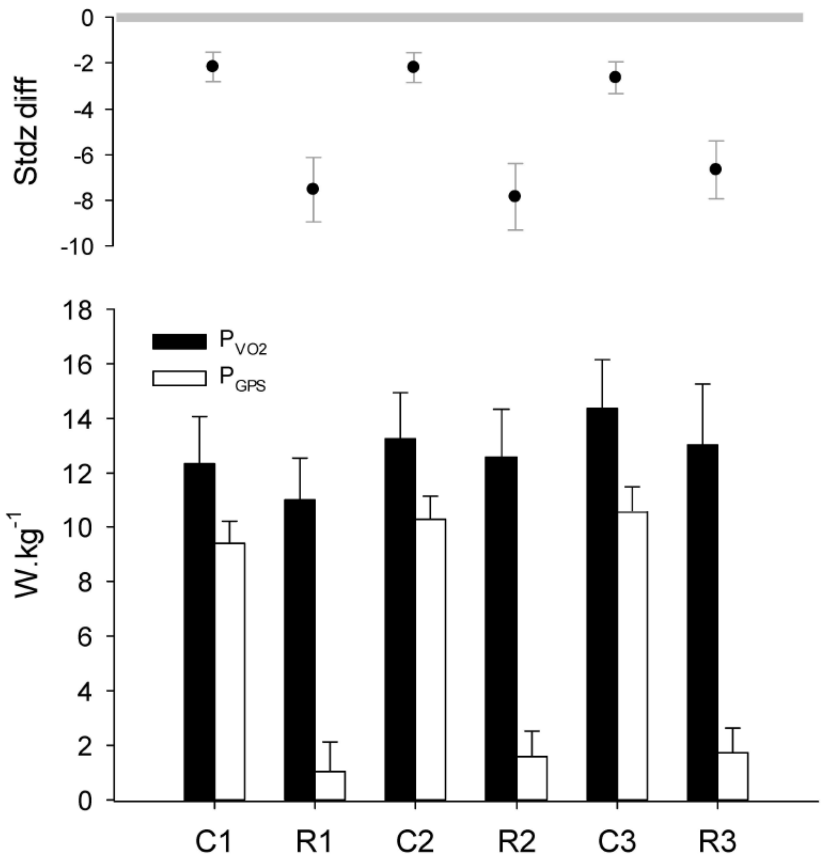

Figure 4; Comparison between MP VO2 and MP GPS (Buchheit et al., 2015)

Another important study from Robertson et al. (2016) trying to investigate the real efficiency of MP. Twenty-seven healthy adults were selected, each participant completed one 90 minute exercise session on an outdoor pitch. To measure velocity and acceleration, participants wore a 5 Hz GPS unit interpolated to a 15 Hz sampling rate (SPI HPU, GPSports Pty Ltd, Australia). Energy expenditure was calculated within the software from GPS derived velocity data and metabolic power estimates based on the di Prampero model (2005), with adaptations from Osgnach et al. (2010). Indirect open-circuit calorimetry (Metamax® 3B, Cortex Pty Ltd, Germany) was used to measure VO2 derived EE to validate the GPS tracking system. Prior to the beginning of the exercise session, the participant was required to be seated for 10 minutes to determine resting measurements of EE for the VO2 derived EE. Mean resting EE was calculated from this 10 minute period, which was subtracted from all subsequent measures of EE during the 90 minutes exercise session. Removing resting EE in this way ensured that all subsequent data used for analysis were directly related to the exercise undertaken, and is consistent with the approach used by Buglione and di Prampero[92]. The exercise session comprised of six parts, each followed by 10 minutes of rest. The exercise bouts were 5 minutes each of walking, jogging, running and three bouts of a simulated field sports circuit. The velocity of the walk, jog and run were 4 km/h, 8 km/h and 12 km/h. The field sports circuit used in this study was a modified version of a circuit designed to replicate the intermittent movement patterns of field sports[93].

Results revealed that MP was significantly higher for the GPS metabolic power compared to the VO2 derived during the walk (% difference = 43.0%), however, it was significantly lower in each of the circuit bouts (-42.2 – -45.8%). There were no significant differences between MP measured using the GPS metabolic power and VO2 derived MP for the jog (7.8%) or run (4.8%). The GPS metabolic power model was unable to accurately estimate MP during walking (a very large overestimation) or intermittent movement patterns that are typical of field sports (a very large underestimation). However, the GPS derived an estimation of MP was reasonably accurate during jogging and running.

The aim of this elaborate will be to investigate through an analysis protocol the differences between MP detected through K4 Cosmed b2 (Golden Standard) and that one obtained by indirect calculation of GPS 50Hz (K-Sport, Montelabbate, Italy). The idea of the project derives from a profound analysis

[92] Buglione A, Di Prampero P.E., "The energy cost of shuttle running." Eur. J. Appl. Physiol. 2013;113(6):1535-1543.
[93] Bishop D, Spencer M, Duffield R, Lawrence S. The validity of a repeated sprint ability test. J. Sci. Med. Sport. 2001;4(1):19-29.

of the specific literature, which showed the numerous inaccuracies of the theoretical model of the MP, the points we try to criticize are:

- The whole theory is based on the formula of Minetti et al. which investigates the energy consumption of the uphill race, but the study was developed by analyzing 10 elite athletes practicing endurance mountain racing, a sport that has a PPM very different from footballers. Therefore the formulas obtained are influenced by the physiological peculiarities of the athletes analyzed, which are very different from those of soccer;
- The formula does not take into account individual differences but refers to an average which obviously can not be applied correctly to everyone, as also demonstrated in the studies listed above;
- The fitness level of the athletes, the weight, height, age or sex of the subjects to be tested is not taken into consideration, a subject with little training, will need more oxygen to perform a certain intensity when compared to professional athletes, while in the theoretical model every human being is defined in the same way;
- The GPS system obtains MP data through the displacements, therefore during the stopping phases, it does not record energetic expenditure, while in the physiological field using a metabolimeter it is possible to analyze the respiratory drift in post-exercise.

3 Research Projects

The Ph.D. projects are divided into two parts, the first will investigate the differences in detection found between GPS and metabolimeter in evaluation of energetic effort during training and matches, the second part will analyze the physical performance during the competitions of the first series of Armenian championship, then comparing the data with those found in the major European championships. Previously we have analyzed the reference data and the most update researches with regard to the respective fields, then we will confine ourselves to exposing only the protocol, means and methods used and data analysis.

3.1 Means and Methods

In the development of the two protocols different hardware have been used, they will be described with precision in the section following.

3.1.1 K-Sport GPS

In the protocol connected with MP comparison between GPS and K4 b2 was used the new GPS system K-Sport 50Hz (Montelabbate, Italy) following specific description:

- 50Hz Real sampling frequency;
- IMU (Accelerometer & Gyroscope): 3D 100Hz;
- Transmission of raw data in real time to the computer;
- Report automatically uploaded on the cloud;
- Under development: the device is positioned on the back of the sensorized shirt, and it’s connected directly to the ECG signal through textile sensors and textile cables;
- LIVE antenna manages 25 devices and 25.000 data per second in real time.

The second research was made using 25 GPSK-Sport 10Hz, following a comparison between the systems.

	K-NEXT	K-LIVE
Type	GPS	GPS + HR + IMU + LIVE
GPS real frequency	10Hz	50Hz
GPS antenna: N°/position	1/back	1/back
Accelerometer	-	100Hz 3D 16G
Gyroscope	-	100HZ 3D
Heart rate	Textile sensors + HR device	Textile sensors
Weight	63g	69g
Size	69x49x19mm	79x49x17mm
Battery	14h	6h
Memory	14h	Unlimited
Downloading type	USB HUB in parallel (all units at the same time)	Live
Downloading time	10-20 seconds per session	Live
PC connection	USB	Wireless
Live	-	Yes
Recharge	USB	Docking station

Table 5; Technical Schedule of K-Sport GPS, comparisons between 10 Hz and 50 Hz

3.1.2 Cosmed K4 b2

The K4 b2 is a portable metabolimeter breath by breath build by Cosmed (Roma, Italy), this system was validated by McLaughlin et al. (2001)[94]. The size

[94] McLaughlin J.E, King G.A, Howley E.T., DR Basset D.R and Ainsworth B.E., "Validation of the Cosmed K4 b2 portable metabolic system", International journal of Sports Medicine, 2001, p. 280-284.

and weight make it this system easily to us in outdoor sports analysis. The most relevant technical features of this device are:

- A turbine system for monitoring breath flows;

- A "mixing chamber" for the sampling of O2 and CO2 concentrations in the expired air;

- A micro-pump and a mask capable of drawing directly from the mouth a sample of air of reduced volume but with a composition identical to that of the total expired gas;

- A temperature detector;

- Analyzes of gas flows and concentrations, "miniaturized and particularly rapid", such as to make possible a "breath by breath" analysis of the main metabolic parameters.

- Polar bend to monitories heart rate during analysis.

The analyzed subject have to wear a "Hans-Rudolph" facemask with unidirectional valves and a special harness. The data, directly stored in the detection unit, are then transferred to the PC and analyzed using the special "Cosmed 7.0" software.

Figure 5; The Cosmed K4 b2, central unit and mask.

The K4 before start a test, need to be calibrated, will follow a short guide to the main controls needed:

1. Air calibration; required by the system before each test, consists of sampling ambient air. Update the CO2 analyzer baseline and gain the O2 analyzer, in order to match the values read with the theoretical environmental values (20.93% for O2 and 0.03% for CO2);
2. Calibration of reference gases; recommended daily, consists of sampling a gas with a known composition (16.00% O2 and 5.00% CO2) from a calibration bottle, and in updating the baseline and gain of the analyzers;
3. Delay calibration; recommended at least once a week or when the sampling tube is replaced is necessary to accurately measure the time required for the gas to pass through the pneumatic circuit before it is analyzed;
4. Turbine calibration; recommended at least quarterly, consists of measuring the volume of a 3-liter calibration syringe and updating the flow meter gain.

3.2 Metabolic Power Comparison Research Project

The aim of this research was to compare the MP theoretical method approach of Osgnach et al. (2010) with a golden standard, using a portable metabolimeter to analyze VO2 and MP values during a different type of running and at a different velocity. Two different protocols were used, the first one was executed on 20 amateur footballers from 7^{Th} Italian League (Age: 27,3 ± 3,3, eight: 1,77 ± 3,4 and weight: 80 ± 4,5). The test protocol was performed using a K4 b2 portable metabolimeter and a 50 Hz Live GPS (K-Sport, Montelabbate, Italy). Subjects had to run at 2 velocities 8 Km/h and at 16 Km/h, 5 minutes for both, and performing a 5 minutes pause between the two. Test were performed in 3 different days in a grass football field. The type of running was circular, asking to players to maintain the velocity without performing changes of speed or direction, in order to help were accommodated some cones around the route (Figure 6).

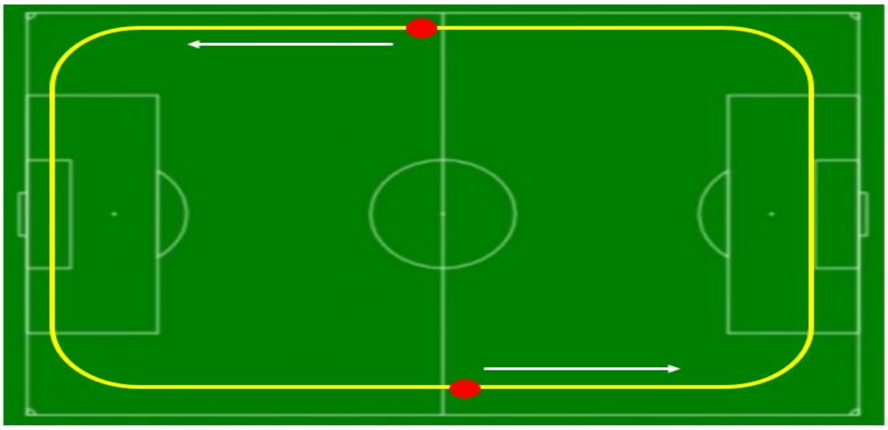

Figure 6; Example of a route

Data from K4 and GPS were at first analyzed separately with use of the specific software, and after data were collected in an Excel Spreadsheet in order to build a pivotal table, to organize and better analyze data. In order to obtain the MP from K4 data, the VO2 was divided for 2,85 as reported in Osgnahc et al. (2010)[95].

K4-MP = VO2/2,85

The second protocol was used in order to better define and investigate differences between MP calculated from GPS (external load) and the MP from K4 (internal load), we introduced two resting periods following the idea of Buchheit et al. (2015) and using a different sample, 20 semi-professional football players (Age: 26,3 ± 3,6, eight: 1,78 ± 4,5 and weight 77 ± 4,3) from a football team of 4[Th] Italian Championship league. Change the sample was important in order to investigate the possible differences that can be recorded

[95] Osgnach C., Poser S., Bernardini R., Rinaldo R. and Di prampero P.E, "Energy Cost and Metabolic Power in Elite Soccer: A New Match Analysis Approach" Medicine and science in sports and exercise · January 2010

between amateur and semi-professional athletes. The test protocol it was so composed:

- Rest Analysis (RE); 3 minutes, analyze athlete during resting phase was useful to define the individual differences of basal metabolism;
- 6 Km/h Jogging: 3 minutes;
- 12 Km/h Running: 3 minutes;
- 16 Km/h Running at High Intensity: 3 minutes;
- Non-constant Running (NC): 3 minutes of free accelerations and decelerations;
- Recovery Phase (RC); 3 minutes of recovery post-exercise in order to analyze the time useful to come back to an initial state pre-exercise.

For a total time of 18 minutes of test for each athlete. Tests were performed around a grass field, in 3 different days, the type of running was circular asking players to maintain the velocity without performing changes of speed or direction (for the first 3 step of test) and for last step the athletes were left free to accelerate and decelerate at individual will, in order to help running were accommodated some cones around the route (Figure 6). Data from K4 and GPS were at first analyzed separately with use of the specific software, and after data were collected in an Excel Spreadsheet in order to build a pivotal table, to organize and better analyze data. In order to obtain the MP from K4 data, the VO2 was divided for 2,85 as reported in Osgnahc et al. (2010)[96].

K4-MP = VO2/2,85

In both tests, we were using the same hardware 5 GPS 50 Hz (K-Sport, Montelabbate, Italy) and one K4 b2 (Cosmed, Roma), and the velocity was live monitored with the use of specific software K-Fitness and live wireless antenna.

[96] Ibid.

3.2.1 Data Analysis

The first protocol was performed from 20 amateur football players, they performed a 15 minutes test, this made: a standard warm-up, 5 minutes of circular constant running at 8 Km/h, 5 minute of resting and 5 minutes of circular constant running at 16 Km/h. Was calculated the Efficiency percentage, in order to understand the differences between internal effort (K4-MP) detected with K4 b2 and external effort (GPS-MP) with GPS, the used formula was:

% Efficiency = ((GPS-MP – K4MP)/ (GPS-MP))* 100

Table 6 shows data from the first part of the test, 8 Km/h MP comparison, 10 players registered a positive comparison that means that the data from GPS were overestimated the internal load, the players were more efficient, 6 players registered a negative comparison this means that data from GPS were underestimated the internal load and 4 players registered a neutral comparisons that mean that were not significant differences between GPS-MP and K4-MP. The average data recorded for 8 Km/h test were: GPS-VO2 29,98 ± 1,21 ml/kg/min, K4-VO2 29,99 ± 2,38, GPS-MP 10,52 ± 0,42 W/kg, K4-MP 10,52 ± 0,84 and the % Efficiency showed a 5,75 % ± 7,2 differences.

8 Km/h Test					
Players	**GPS-VO2**	**K4-V02**	**GPS-MP**	**K4-MP**	**% Efficiency**
1	31,11	29,89	10,92	10,49	3,92%
2	30,05	33,45	10,54	11,74	-11,31%
3	29,78	27,44	10,45	9,63	7,86%
4	30,11	30,18	10,56	10,59	-0,23%
5	32,20	29,30	11,30	10,28	9,01%
6	28,78	31,60	10,10	11,09	-9,81%
7	29,42	28,45	10,32	9,98	3,30%
8	31,13	30,55	10,92	10,72	1,86%
9	31,25	30,88	10,96	10,84	1,18%
10	30,65	34,66	10,75	12,16	-13,08%
11	29,00	28,65	10,18	10,05	1,21%
12	28,88	30,67	10,13	10,76	-6,20%
13	30,01	30,11	10,53	10,56	-0,33%
14	31,45	29,55	11,04	10,37	6,04%
15	29,50	26,45	10,35	9,28	10,34%
16	27,88	26,34	9,78	9,24	5,52%
17	28,85	31,55	10,12	11,07	-9,36%
18	27,90	26,55	9,79	9,32	4,84%
19	30,33	29,30	10,64	10,28	3,40%
20	31,22	34,23	10,95	12,01	-9,64%
Average	**29,98**	**29,99**	**10,52**	**10,52**	**5,75%**

Table 6; Data from 8 Km/h test comparison

Table 7 shows data from the second part of the test, 16 Km/h MP comparison,10 players showed a positive comparison this means that GPS was overestimated the internal load, 6 players showed negative comparison this means that GPS were underestimated the internal load and 4 players showed neutral comparisons this means that no significant differences were founded. The average data recorded for 16 Km/h test were: GPS-VO2 53,47 ± 3,82 ml/kg/min, K4-VO2 52,04 ± 6,27 ml/kg/min, GPS-MP 18,76 ± 1,34 W/kg, K4-MP 18,26 ± 2,20 W/kg and the % Efficiency showed a 8,95 % ± 11,1 differences.

16 Km/h Test					
Players	**GPS-VO2**	**K4-V02**	**GPS-MP**	**K4-MP**	**% Efficiency**
1	47,95	45,01	16,82	15,79	6,13%
2	52,31	59,12	18,35	20,74	-13,02%
3	52,31	50,33	18,35	17,66	3,79%
4	55,00	54,78	19,30	19,22	0,40%
5	53,53	44,93	18,78	15,76	16,07%
6	48,60	55,40	17,05	19,44	-13,99%
7	44,78	36,38	15,71	12,76	18,76%
8	49,76	48,89	17,46	17,15	1,75%
9	56,00	55,44	19,65	19,45	1,00%
10	52,75	61,00	18,51	21,40	-15,64%
11	57,22	57,45	20,08	20,16	-0,40%
12	57,20	59,00	20,07	20,70	-3,15%
13	56,80	57,45	19,93	20,16	-1,14%
14	54,90	48,62	19,26	17,06	11,45%
15	54,90	48,62	19,26	17,06	11,45%
16	53,60	50,55	18,81	17,74	5,69%
17	55,37	58,00	19,43	20,35	-4,75%
18	56,58	45,95	19,85	16,12	18,79%
19	60,44	48,62	21,21	17,06	19,56%
20	49,32	55,33	17,31	19,41	-12,19%
Average	**53,47**	**52,04**	**18,76**	**18,26**	**8,95%**

Table 7; Data from 16 Km/h test comparison

Is important to notice that in both tests the same players showed the same efficiency 10 overestimated, 6 underestimate and 4 show a neutral comparison, this means that they had the same value in K4-MP and GPS-MP, this means that in this case, a player that had an overestimated data at 8 Km/h recorded another overestimation at 16 Km/h. With higher intensity grow up even the %Efficiency that was 5,75% ± 7,2 in 8 Km/h test and 8,95 % ± 11, even the higher standard deviation shows us that at high intensity there is more probability to detect higher differences between GPS-MP and K4-MP.

The %Efficiency show us if players have a better or worst efficiency ratio comparing the golden standard (K4) to the theoretical method of Di Prampero calculated using external effort from GPS. A positive efficiency means that the player, use less energy of what it should theoretically use to maintain that intensity, on the other hand when a player shows a negative efficiency means that he uses more energy of that it should theoretically use. In 40 analysis only 7 times (17,5%) the comparisons were neutral this means that there were no differences or at least not significant between GPS-MP and K4-MP.

The second protocol was performed from 20 semi-professional football players, they performed an 18 minutes test, the protocol it was so composed:

- Basal Metabolism Analysis (BM); 3 minutes, analyze athlete during resting phase in standing position was useful to define the individual differences of basal metabolism;
- 6 Km/h Jogging: 3 minutes;
- 12 Km/h Running: 3 minutes;
- 16 Km/h High Intensity Running: 3 minutes;
- Non-constant Running (NC): 3 minutes of free accelerations and decelerations;
- Recovery Phase (RC); 3 minutes of recovery post-exercise in standing position in order to analyze the time useful to come back to an initial state pre-exercise.

Table 8 shows an example of the individual analysis of one player, in this specific case, is possible to notice that at 6 Km/h the GPS-MP was overestimated but that in the following velocity 12 Km/h, 16 Km/h and N.C there was underestimation, the percentage of efficiency increases with increasing of test intensity.

It is obvious that in all the tests the BM and the RC part showed a 0 value in GPS-V02 and consequently in K4-MP, this shows the greater criticality of the theoretical method of Osgnach et al. (2010), that use external effort to evaluate the MP.

Players	Steps	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
1	*BM*	0	4,66	0	1,6	---
1	*6 Km/h*	24,22	23,55	8,5	8,3	2,8%
1	*12 Km/h*	41,45	43,45	14,5	15,2	-4,8%
1	*16 Km/h*	50,44	54,43	17,7	19,1	-7,9%
1	*N.C*	40,44	44,46	14,2	15,6	-9,9%
1	*RC*	0	18,44	0	6,5	---

Table 8; Example of data from the second protocol test

A high value in K4-MP during the RC step, show that that athlete had a slow recovery in post-exercise phase, this can help coaches to individualize training in order to improve and work on individual shortcomings.

Table 9 shows data from BM phase, as was known GPS data detected GPS-V02 and GPS-MP as 0, this because GPS use date of external load to calculate these parameters. In this case there is no possible comparison, average of K4-V02 was 4,74 ± 0,50 ml/kg/min and K4-MP 1,66 ± 0,18 W/kg. This analysis suggests us the idea that to better define the individual GPS-MP, can be possible to evaluate the BM and after using the specific GPS software to set up the individual value for every player, in order to subtract it to the instant output like in this example:

GPS-MP = (GPS-VO2 – BM)/2,85

Basal Metabolism Analysis (BM)					
Players	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
1	0	4,66	0	1,64	---
2	0	3,68	0	1,29	---
3	0	3,88	0	1,36	---
4	0	4,70	0	1,65	---
5	0	4,56	0	1,90	---
6	0	5,22	0	1,83	---
7	0	4,33	0	1,52	---
8	0	4,29	0	1,51	---
9	0	5,66	0	1,99	---
10	0	5,34	0	1,87	---
11	0	4,44	0	1,56	---
12	0	4,37	0	1,53	---
13	0	4,77	0	1,67	---
14	0	5,26	0	1,85	---
15	0	4,88	0	1,71	---
16	0	4,76	0	1,67	---
17	0	5,13	0	1,80	---
18	0	5,33	0	1,60	---
19	0	4,90	0	1,72	---
20	0	4,50	0	1,58	---
Average	**0**	**4,73**	**0**	**1,66**	**---**

Table 9; Players Data from BM phase

Table 10 shows data from 6 Km/h phase, average data were: GPS-VO2 24,48 ± 0,68 ml/kg/min, K4-V02 23,66 ± 0,24 ml/kg/min, GPS-MP 8,59 ± 0,24 W/kg, K4-MP 8,30 ± 0,26 W/kg and % Efficiency 3,70 ± 2,65 %. The % Efficiency shows us that 14 players recorded an overestimation of GPS-MP, 5 players show a neutral comparison that means that the GPS was able to detect data near or equal to the K4-MP and only 1 player shows an underestimation of the GPS-MP.

6 Km/h Jogging					
Players	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
1	24,22	23,55	8,50	8,26	2,77%
2	24,66	23,41	8,65	8,21	5,07%
3	25,32	23,79	8,88	8,35	6,04%
4	24,70	23,95	8,67	8,40	3,04%
5	23,89	24,66	8,38	8,65	-3,22%
6	23,79	22,56	8,35	7,92	5,17%
7	22,90	23,06	8,04	8,09	-0,70%
8	23,44	23,20	8,22	8,14	1,02%
9	24,44	23,56	8,58	8,27	3,60%
10	24,90	23,78	8,74	8,34	4,50%
11	24,67	24,32	8,66	8,53	1,42%
12	25,22	25,10	8,85	8,81	0,48%
13	25,67	24,80	9,01	8,70	3,39%
14	25,21	23,23	8,85	8,15	7,85%
15	24,69	23,56	8,66	8,27	4,58%
16	24,90	24,20	8,74	8,49	2,81%
17	23,88	22,48	8,38	7,89	5,86%
18	24,50	23,32	8,60	8,18	4,82%
19	23,98	22,50	8,41	7,89	6,17%
20	24,54	24,12	8,61	8,46	1,71%
Average	**24,48**	**23,66**	**8,59**	**8,30**	**3,70%**

Table 10; Players Data from 6 Km/h Jogging

Table 11 shows data from 12 Km/h phase, average data were: GPS-VO2 40,54 ± 1,09 ml/kg/min, K4-V02 42,42 ± 1,75 ml/kg/min, GPS-MP 14,22 ± 1,75 W/kg, K4-MP 14,89 ± 0,61 W/kg and % Efficiency 5,12 ± 2,73 %. The % Efficiency shows us that 16 players recorded an underestimation of GPS-MP, 3 players show a neutral comparison that means that the GPS was able to detect data near or equal to the K4-MP and only 1 player shows an overestimation of the GPS-MP. Data show that raising the intensity level of the exercise, we will obtain fewer cases of overestimation, while those of underestimation will grow. Prior to the 6 km/h jogging speed, there were 14 cases of overestimation, while now there is only one case.

12 Km/h Running					
Players	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
1	41,45	43,45	14,54	15,25	-4,83%
2	42,65	43,78	14,96	15,36	-2,65%
3	40,13	42,45	14,08	14,89	-5,78%
4	41,45	39,55	14,54	13,88	4,58%
5	40,89	43,43	14,35	15,24	-6,21%
6	41,34	44,60	14,51	15,65	-7,89%
7	41,66	43,63	14,62	15,31	-4,73%
8	41,55	42,56	14,58	14,93	-2,43%
9	41,89	44,66	14,70	15,67	-6,61%
10	40,90	43,23	14,35	15,17	-5,70%
11	39,79	40,23	13,96	14,12	-1,11%
12	38,99	39,45	13,68	13,84	-1,18%
13	40,33	43,32	14,15	15,20	-7,41%
14	39,76	44,33	13,95	15,55	-11,49%
15	38,79	40,21	13,61	14,11	-3,66%
16	38,56	40,30	13,53	14,14	-4,51%
17	40,44	42,30	14,19	14,84	-4,60%
18	40,12	43,34	14,08	15,21	-8,03%
19	40,15	43,43	14,09	15,24	-8,17%
20	39,88	40,22	13,99	14,11	-0,85%
Average	**40,54**	**42,42**	**14,22**	**14,89**	**5,12%**

Table 11; Players Data from 12 Km/h Running

Table 12 shows data from 16 Km/h phase, average data were: GPS-VO2 52,13 ± 1,28 ml/kg/min, K4-V02 55,16 ± 1,41 ml/kg/min, GPS-MP 18,29 ± 0,45 W/kg, K4-MP 19,35 ± 0,50 W/kg and % Efficiency 5,93 ± 2,91 %. The % Efficiency shows us that 19 players recorded an underestimation of GPS-MP and that only one player shows a neutral comparison that means that the GPS was able to detect data near or equal to the K4-MP. Data show that raising the intensity level of the exercise, we will obtain less or null cases of overestimation, while those of underestimation will grow. Prior to the 12 km/h Running speed, there was 1 case of overestimation, while now no one.

16 Km/h High Intensity Running					
Players	**GPS-VO2**	**K4-V02**	**GPS-MP**	**K4-MP**	**% Efficiency**
1	50,44	54,43	17,70	19,10	-7,91%
2	52,55	55,70	18,44	19,54	-5,99%
3	50,32	55,49	17,66	19,47	-10,27%
4	52,78	55,60	18,52	19,51	-5,34%
5	53,22	57,32	18,67	20,11	-7,70%
6	51,96	55,32	18,23	19,41	-6,47%
7	51,44	57,56	18,05	20,20	-11,90%
8	50,56	55,32	17,74	19,41	-9,41%
9	49,98	51,30	17,54	18,00	-2,64%
10	50,16	55,23	17,60	19,38	-10,11%
11	51,88	54,32	18,20	19,06	-4,70%
12	53,63	53,22	18,82	18,67	0,76%
13	53,44	54,32	18,75	19,06	-1,65%
14	54,33	57,30	19,06	20,11	-5,47%
15	52,68	55,45	18,48	19,46	-5,26%
16	52,33	55,45	18,36	19,46	-5,96%
17	51,99	54,33	18,24	19,06	-4,50%
18	52,33	54,43	18,36	19,10	-4,01%
19	53,34	55,43	18,72	19,45	-3,92%
20	53,21	55,69	18,67	19,54	-4,66%
Average	**52,13**	**55,16**	**18,29**	**19,35**	**5,93%**

Table 12; Player Data from 16 Km/h High-Intensity Running

Table 13 shows data from NC phase, average data were: GPS-VO2 43,75 ± 2,05 ml/kg/min, K4-V02 46,99 ± 2,76 ml/kg/min, GPS-MP 15,35 ± 0,71 W/kg, K4-MP 16,49 ± 0,97 W/kg and % Efficiency 9,20 ± 3,87 %. The % Efficiency shows us that 17 players recorded an underestimation of GPS-MP and that 3 players show an overestimation of GPS-MP, no neutral efficiencies were founded. Data show that raising the intensity level of the exercise, we will obtain less or null cases of overestimation, while those of underestimation will grow.

Non-constant Running (NC)					
Players	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
1	40,44	44,46	14,19	15,60	-9,94%
2	39,56	43,33	13,88	15,20	-9,53%
3	42,46	44,67	14,90	15,67	-5,20%
4	44,70	43,80	15,68	15,37	2,01%
5	47,23	45,60	16,57	16,00	3,45%
6	45,67	40,56	16,02	14,23	11,19%
7	45,44	48,88	15,94	17,15	-7,57%
8	43,36	48,70	15,21	17,09	-12,32%
9	42,89	48,67	15,05	17,08	-13,48%
10	41,69	47,54	14,63	16,68	-14,03%
11	43,22	48,32	15,16	16,95	-11,80%
12	41,89	47,56	14,70	16,69	-13,54%
13	42,33	46,32	14,85	16,25	-9,43%
14	43,12	45,32	15,13	15,90	-5,10%
15	43,34	48,78	15,21	17,12	-12,55%
16	44,88	46,66	15,75	16,37	-3,97%
17	45,65	52,33	16,02	18,36	-14,63%
18	46,79	50,32	16,42	17,66	-7,54%
19	45,69	48,45	16,03	17,00	-6,04%
20	44,69	49,44	15,68	17,35	-10,63%
Average	**43,75**	**46,99**	**15,35**	**16,49**	**9,20%**

Table 13; Players Data from Non-constant Running

Table 14 shows data from RC phase, as was known GPS data detected GPS-V02 and GPS-MP as 0, this because GPS use date of external load to calculate these parameters. In this case, there is no possible comparison, an average of K4-V02 was 10,47 ± 3,06 ml/kg/min and K4-MP 3,67 ± 1,07 W/kg. This analysis suggests us the idea that to better define the individual GPS-MP during recovery phase following high-intensity exercises or actions, can be possible to evaluate the RC using the individual value of K4-MP detected previously with a specific test and subsequently using the specific GPS software to set up the individual value for every player. Unfortunately, this approach seems impossible now for several factors:

- The impossibility to carry out a test at all the intensities and durations of exercise/action possible during a race and a training;

- It is not possible to calculate precisely how much the post-exercise energy cost is kept high and does not return to baseline;

- MP values are influenced by numerous external and internal variables.

Recovery Phase (RC)					
Players	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
1	0	18,44	0	6,47	---
2	0	9,43	0	3,31	---
3	0	11,44	0	4,01	---
4	0	9,33	0	3,27	---
5	0	10,11	0	3,55	---
6	0	8,45	0	2,96	---
7	0	8,66	0	3,04	---
8	0	9,45	0	3,32	---
9	0	9,79	0	3,44	---
10	0	10,45	0	3,67	---
11	0	11,32	0	3,97	---
12	0	9,69	0	3,40	---
13	0	8,89	0	3,12	---
14	0	10,33	0	3,62	---
15	0	19,57	0	6,87	---
16	0	8,89	0	3,12	---
17	0	7,79	0	2,73	---
18	0	8,68	0	3,05	---
19	0	9,34	0	3,28	---
20	0	9,27	0	3,25	---
Average	**0**	**10,47**	**0**	**3,67**	**---**

Table 13; Players Data from RC phase

Table 14 shows average data from all players including the standard deviation, is possible to observe that the % Efficiency growing up with the increasing of intensity starting from to 3,70% ± 2,65 and reaching the value of 9,20% ± 3,87, the growing up of standard deviation, evidence that as the intensity increases, the individual difference in the sample increases, as physiology teaches. Also is important to highlight that between the VO2 and MP detected with GPS and K4, there is always a higher standard deviation in values mistreated with K4, this because the internal effort present obviously more differences between players and is regulated by the physiology of each individual, in the other and the GPS is modulated only by the velocity and changes of acceleration. Anyway, there was a natural standard deviation even in data from GPS because even if during tests, every player were monitored in live, is more or less impossible to keep the same speed for 3 minutes without making changes in speed or acceleration.

In total detections 80 only 9 (11,25%) showed a neutral comparison this means that there were no differences or at least not significant between GPS-MP and K4-MP (Table 15).

Phase	GPS-VO2	K4-V02	GPS-MP	K4-MP	% Efficiency
BM	0	4,73 ± 0,50	0	1,66 ± 0,18	---
6 Km/h	24,48 ± 0,68	23,66 ± 0,74	8,59 ± 0,24	8,30 ± 0,26	3,70% ± 2,65
12 Km/h	40,54 ± 1,09	42,42 ± 1,75	14,22 ± 0,38	14,89 ± 0,61	5,12% ± 2,73
16 Km/h	52,13 ± 1,28	55,16 ± 1,41	18,29 ± 0,45	19,35 ± 0,50	5,93% ± 2,91
NC	43,75 ± 2,05	46,99 ± 2,76	15,35 ± 0,71	16,49 ± 0,97	9,20% ± 3,87
RC	0	10,47 ± 3,06	0	3,67 ± 1,07	---

Table 14; Average Data and standard deviation divided by Phase

Phase	Underestimation	Overestimation	Neutral
BM	20	0	0
6 Km/h	1	14	5
12 Km/h	16	1	3
16 Km/h	19	0	1
NC	17	3	0
RC	20	0	0

Table 15; % Efficiency Results

3.2.2 Discussion

The aim of this study was to investigate and determinate the efficiency of the MP theoretical model of Osgnach et al. (2010), previous studies were trying to make focus on this Stevens et al. (2014), Buchheit et al. (2015) and Robertson et al. (2016), obtaining different results, but still showing the lack of reliability in the determination of the MP by indirect calculation. In our case, the use of a precise protocol and a new generation of GPS gauges with a frequency of 50 Hz and the possibility to check the speed data in live, has allowed us to analyze in depth the relationship between GPS-MP and K4 -MP.

To better analyze the event we proposed two different test, first was performed by 20 amateur football players from 7Th Italian League, and it was so composed: 5 minutes of continues running at 8 Km/h, 5 minutes pause and 5 minutes of continues running at 16 Km/h, for a total of 15 minutes of test for every player.

The second one was performed by 20 semi-professional football players from a football team of 4Th Italian Championship league. Change the sample was important in order to investigate the possible differences that can be recorded between amateur and semi-professional athletes. The test protocol it was so composed:

- Rest Analysis (RE); 3 minutes, analyze athlete during resting phase was useful to define the individual differences of basal metabolism;
- 6 Km/h Jogging: 3 minutes;
- 12 Km/h Running: 3 minutes;
- 16 Km/h Running at High Intensity: 3 minutes;
- Non-constant Running (NC): 3 minutes of free accelerations and decelerations;
- Recovery Phase (RC); 3 minutes of recovery post-exercise in order to analyze the time useful to come back to an initial state pre-exercise.

All data from both tests were analyzed in order to evaluate the comparison between GPS-MP and K4-MP (Table 16).

In the first test, 13 players the 32,5% recorded an underestimation of GPS-MP, 20 players the 50% recorded an overestimation and 7 players the 17,5% recorded a neutral comparison. This means that the correlation between GPS-MP and K4-MP was positive only in the 17,5% of cases.

In the second test, 53 players the 66,3 detected an underestimation, 18 players 22,5% detected an overestimation and 7 players 11,2% showed a neutral comparison. This means that the correlation between GP-MP and K4-MP was positive only in 11,2% of cases.

In total 66 players the 55% showed an underestimation, 38 players the 31,6% detected an overestimation and 16 players the 13,4% showed a neutral comparison.

In 120 detections only the 13,4% were showing a correlation between GPS-MP and K4-MP.

Test	**Underestimation**	**Overestimation**	**Neutral**
First	13	20	7
Second	53	18	9
Total	66	38	16

Table 16; Results from first and second protocol

3.3 Armenian Premier League Match Performance Analysis Research Project

The aim of this research was to analyses the PPM of Armenian Premier League using 25 GPS 10 Hz (K-Sport, Montelabbate, Italy), in order to compare data obtained with literature from major European championship. In total were analyzed 25 matches (10 wins, 10 loses and 5 draws), 33 different players (age 24,3 ± 4,2, eight 1,76 ± 4,2 and weight 74 ± 3,5) and in total 270 performances (10,8 for matches). Were analyzed 37 central defenders (CD), 45 full-backs (FB), 66 central midfielders, 44 external midfielders, 28 forwards and 50 substitutions (average for matches 2,0). The substituted players played in 36 cases less than 45 minutes and in 14 cases the entire second half. Matches were divided in First Half (T1), Second Half (T2),), First Half Substitution (T1 Sub), Second Half Substitution (T2 Sub), Full Match, Full Match Substitution (Full Match Sub) and Total Match (Total) that include all the players detected during a games. Furthermore, all matches were divided even by quarters 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90, only players that playing all match were included in this analyses, in order to check the performance decreasing during the time. All data were added in an Excel Spreadsheet in order to build a pivotal table, to organize and better analyze data, cataloging events for data, results and if the match was played home or away. The following parameters were taken into consideration:

- Total Distance (meters, D);
- Distance per minutes (meters/minutes, Drel);
- Distance covered at High-Intensity (speed ≥ than 16 km/h, HI);
- Distance covered at High-Metabolic Intensity (MP≥20 watt·kg-1, MPHI);
- Distance at Medium Acceleration > 2 m/s2 (meters, Acc);
- Distance at Medium Deceleration < - 2 m/s2 (meters, Dec);

- Sum of Medium Acceleration and Deceleration (meters, Acc-Dec)
- Average Metabolic Power (W/kg, AMP).

To easier define PPM is possible to divide the total distance covered in each events with the total minutes played in order to find the Relative (Rel) parameter, in this way obtaining an easier number to remember and compare and also having a better idea of the performance performed on average per minute.

3.3.1 Data Analysis

Table 17 shows data from T1 and T2, showing even the decrement percentage (%Dec) from T2 compared with T1. The lower decrement it was recorded in D parameter, 2,86%, HI and MPHI showing the same %Dec (7,24% and 7,29%), a greater decrease can be noted in Dec then Acc and the higher %Dec is showed by MP.

Type	D	HI	MPHI	Acc	Dec	Acc-Dec	MP
T1	4717	694	1214	252	233	485	9,5
T2	4582	644	1125	238	218	456	8,8
% Dec	*2,86%*	*7,24%*	*7,29%*	*5,51%*	*6,53%*	*6,00%*	*7,66%*

Table 17; Average data from all detected matches for T1 and T2

Table 18 shows data from:

- Full Match; players that played all 90' minutes and extra time;
- Full Match Sub; players that were replaced (in and out);
- Total; data from all players that took part of the match.

Type	D	HI	MPHI	Acc	Dec	Acc-Dec	MP
Full Match	9254	1304	2304	488	447	935	9,1
Full Match Sub	5364	877	1447	286	273	559	9,8
Total	7607	1120	1938	402	372	774	9,4

Table 18; Average data from all detected matches

Table 19 and 20 shows data divided by quarters and the percentage of decrease or increase during quarters. Quarters that show higher values of %Dec are the 0-15/15-30 and 45-60/60-75, this means that during the first and second quarters of T1 and T2 is possible to detect the higher decrease. Between last quarter of T1 (30-45) and the first quarter of T2 (45-60) is possible to detect and increase of all parameters.

Type	D	HI	MPHI	Acc	Dec	Acc-Dec	MP
0-15	1647	256	450	93	85	178	10,3
15-30	1529	223	387	79	74	153	9,4
30-45	1456	203	355	75	69	145	9,0
45-60	1512	233	393	81	75	156	9,3
60-75	1402	194	338	73	67	140	8,6
75-90	1389	178	324	70	63	133	8,5

Table 19; Average data from quarters

Type	D	HI	MPHI	Acc	Dec	Acc-Dec	MP
0-15/15-30	-8%	-15%	-16%	-18%	-15%	-16%	-10%
15-30/30-45	-5%	-10%	-9%	-5%	-7%	-6%	-4%
30-45/45-60	4%	13%	10%	7%	8%	7%	3%
45-60/60-75	-8%	-20%	-16%	-11%	-12%	-11%	-8%
60-75/75-90	-1%	-9%	-4%	-4%	-6%	-5%	-1%

Table 20; Percentage of decrease or increase between quarters

Table 21 shows data from all players divided by roles:

- CD, show the lowest values in HI, MPHI, Dec and Acc-Dec, and an average value in Acc;
- FB, show average values in D, HI, MPHI, and MP and the highest values in Acc and Acc-Dec;
- CM, show the lowest value in Acc, average values in Dec and Acc-Dec and the highest values in D and MP;
- EM, show the highest values in HI, MPHI, and Dec;
- FO, show the lowest values in D and MP.

Role	D	HI	MPHI	Acc	Dec	Acc-Dec	MP
CD	8575	863	1881	483	405	888	8,4
FB	9174	1362	2285	518	467	985	9,1
CM	9894	1409	2565	466	448	913	9,6
EM	9611	1638	2576	493	475	968	9,5
FO	8174	1191	1948	471	418	889	8,1

Table 21; Average data from Full Match divided by role

Table 22 contain data from Armenian Full Match including SD, and Max and Min values detected. Table 23, 24 shows data respectively from the European Championship (Castagna et al, 2016) and from Italian Championship (Osgnach et al, 2010).

Armenian Premier League						
Type	**D**	**HI**	**MPHI**	**Acc**	**Dec**	**MP**
Average	9254	1304	2304	488	447	9,1
SD	376	134	172	41	39	0,4
Min	8502	1088	1955	414	377	8,4
Max	9896	1567	2600	545	512	10,0

Table 22; Average data, SD, Min and Max from Armenian Premier League

European Championships						
Type	**D**	**HI**	**MPHI**	**Acc**	**Dec**	**MP**
Average	10672	1778	2759	636	612	10.6
SD	347	208	241	118	97	0.4
Min	9417	1156	2028	397	437	9.1
Max	11595	2310	3344	911	890	12.0

Table 23; Average data, SD, Min and Max from European Championships

Italian Championship						
Type	**D**	**HI**	**MPHI**	**Acc**	**Dec**	**MP**
Average	10950	1996	2839	591	599	10.7
SD	1044	220	601	128	130	0.8

Table 24; Average data, SD, Min and Max from Italian Championship

In table 25 is shown a comparison between different championships using data from our study and from literature, in this case, Italian Championship shows higher value in all parameters except for Acc and Dec that are higher in Euro Championship. Armenian League shows the lowest values in all parameters in comparison with these leagues. One last comparison is showed in table 26 and is between the average data from Euro and Italian leagues and Armenian Premier League, the higher percentage differences are in HI and lower is recorded in D.

Total Comparison						
Type	**D**	**HI**	**MPHI**	**Acc**	**Dec**	**MP**
Euro	10672	1778	2759	636	612	10,6
Italian	10950	1996	2839	591	599	10,7
Armenian	9254	1304	2304	488	447	9,1

Table 25; Comparison between Championships

Type	D	HI	MPHI	Acc	Dec	MP
Euro Average	10811	1887	2799	614	606	10,7
Armenian	9254	1304	2304	488	447	9,1
% Dec	14,40%	30,88%	17,68%	20,38%	26,21%	14,48%

Table 26; Comparison and percentage comparison

One last interesting comparison was made (table 27) correlating the results of games with fitness data, in order to find a correlation between parameters and sports results. No crucial differences were find between results, is interesting how during lost matches is possible to detect higher values in D, HI, and MPHI, parameters of movement, but that talking about high-intensity actions the values are the lowest (Acc, Dec and MP).

Result	D	HI	MPHI	Acc	Dec	MP
Win	9281	1283	2308	500	452	9,2
Lose	9333	1365	2354	477	441	9,1
Draw	9204	1280	2250	496	455	9,1

Table 27; Comparison of data between results from Armenian Premier League

3.3.2 Discussion

The aim of this research was to analyses the PPM of Armenian Premier League using GPS 10 Hz (K-Sport, Montelabbate, Italy), and to compare data obtained with literature from major European championship. Matches were divided in First Half (T1), Second Half (T2),), First Half Substitution (T1 Sub), Second Half Substitution (T2 Sub), Full Match, Full Match Substitution (Full Match Sub) and Total Match (Total) that include all the players detected during a games. Comparing T2 with T1is possible to observe the usual decrease that is described in the literature, the lower decrease value is in D with a 2,86%, HI and MPHI showed same value (7,24% and 7,29%) and the higher decrease is showed in MP 7,66%. The decreasing of Acc (5,51%) is lower of Dec (6,53%), this can be correlated with the deceleration movements are correlated with an eccentric contraction that is more difficult to execute when muscle soreness rise up. It was evaluated even the decreasing during quarters, of course, the higher values were recorded during the first quarter (0-15), the higher %Dec was recorded in the second and fifth quarter (15-30, 60-75). Between the third and fourth quarter (30-45/45-60) was detected an increase of every parameter, this is correlated with the break preset between the T1 and T2. Furthermore, the lower %Dec is recorded between the fifth and sixth quarter (60-75/75-90). The higher values od %Dec during quarters is recorded in HI parameter (-8%) and the lower are equal for D (-4%) and MP (-4%), other parameters shows an average %Dec of MPHI (-7%), Acc (-6%), Dec (-6%) and Acc-Dec (-6%).

Comparing PPM with roles it is possible to discover that:

- CD, show the lowest values in HI, MPHI, Dec and Acc-Dec, and an average value in Acc;
- FB, show average values in D, HI, MPHI, and MP and the highest values in Acc and Acc-Dec;

- CM, show the lowest value in Acc, average values in Dec and Acc-Dec and the highest values in D and MP;
- EM, show the highest values in HI, MPHI, and Dec;
- FO, show the lowest values in D and MP.

In Armenian Premier League FO runs less in D and Acc-Dec then CD and this goes against literature (Ferro et al, 2014), but they coincide with literature in HI, MPHI, and MP that are higher in CM and EM.

Average data from Armenian Premier League in comparison with literature data from European and Italian Championship show that in every parameter, the Armenian Premier League are under the average. This is obviously related to the non-high level of the Armenian football that is in fact placed at the 100° place of the FIFA ranking (update 20 September 2018). Physical data represent an indicator of performance but also of the qualitative level of the league and of individual players. For this reason, the use of the match analysis can be decisive to verify the KPI and the PPM, in order to better evaluate the championships, teams, and players, in order to make the search and the discovery of the sporting talent easier. The use of objective values simplifies and makes a scientific analysis of the performance and consequently also the evaluation of the players. The higher differences between Armenian and European Leagues are in HI, MPHI, Acc and Dec parameters, respectively with a %Dec of 30,88%, 17,68%, 20,38%, and 26,21%. As the literature, shows the high-intensity events are the performance indicators of efficiency and of sport results, more correlated with the possibility of obtaining an advantage in the sport of football.

Comparing GPS data with the result of matches show that in Armenian Premier League, were no significate differences between physical data and type of result (Wins, Loses and Draws).

4 Conclusion

The aims of this doctoral thesis were to analyze the physical performance of soccer players and to relate and compare the intentional and external load through the use of detection hardware and software. The project was divided into two parts, the first was investigated the differences in detection of internal effort between GPS and metabolimter in evaluation of energetic effort during training and matches, the second part was analyzing the physical performance during the competitions of the Armenian Premier League, then comparing the data with those found in the major European championships.

Analyzing the external and internal effort of football is the main goal of the last decade and probably will be even of the next. The results of our researches show that the MP approach cannot be used lightly; coaches and staff have to know the limit of this method in order to don't build and analyze trainings and matches only using MP, but even evaluating other important parameters such as HI, Acc and Dec. The use of K4 and the comparison of K4-MP with the GPS-MP during our test made it possible to understand that there are too many differences between the data estimated by the GPS and the direct one derived from the K4. In the first test, 13 players the 32,5% recorded an underestimation of GPS-MP, 20 players the 50% recorded an overestimation and 7 players the 17,5% recorded a neutral comparison. This means that the correlation between GPS-MP and K4-MP was positive only in the 17,5% of cases. In the second test, 53 players the 66,3 detected an underestimation, 18 players 22,5% detected an overestimation and 7 players 11,2% showed a neutral comparison. The correlation between GP-MP and K4-MP was positive only in 11,2% of cases. In total 66 players the 55% showed an underestimation, 38 players the 31,6% detected an overestimation and 16 players the 13,4% showed a neutral comparison. In 120 detections only the 13,4% were showing a correlation between GPS-MP and K4-MP. These results, let to say that the use of the MP shows considerable limitations, at the moment the use of the MP intended as a synonym of real internal load, cannot be performed with intellectual honesty. To solve these problems, some companies that produce hardware and software for sport, are trying to produce new models of GPS jackets with pulmonary ventilation sensors. The analysis of the actual lung dilatation could allow a much more accurate estimate of the MP, in order to abandon the current derivation method proposed by Osgnach in 2010. Future researches and innovations must be done in this particular field in order to evaluate, the real internal load of players.

Value the real MP result can be crucial for the holistic and preventive evaluation, in order to individualize the methods of training and recovery management, an athlete for athlete.

Analyzing the PPM of the Armenian Premier League allow use to define another aspect of match and training analysis, that is the performance of external effort and the comparison of players and leagues. Comparing T2 with T1is possible to observe the usual decrease that is described in the literature, the lower decrease value is in D with a 2,86%, HI and MPHI showed same value (7,24% and 7,29%) and the higher decrease is showed in MP 7,66%. The decreasing of Acc (5,51%) is lower of Dec (6,53%), this can be correlated with the deceleration movements are correlated with an eccentric contraction that is more difficult to execute when muscle soreness rise up. It was evaluated even the decreasing during quarters, of course, the higher values were recorded during the first quarter (0-15), the higher %Dec was recorded in the second and fifth quarter (15-30, 60-75). Between the third and fourth quarter (30-45/45-60) was detected an increase of every parameter, this is correlated with the break preset between the T1 and T2. Talking about roles, FO runs less in D and Acc-Dec then CD and this goes against literature (Ferro et al, 2014), but they coincide with literature in HI, MPHI, and MP that are higher in CM and EM.

Average data from Armenian Premier League in comparison with literature data from European and Italian Championship show that in every parameter, the Armenian Premier League are under the average.

Physical data represent an indicator of performance but also of the qualitative level of the league and of individual players. For this reason, the use of the match analysis can be decisive to verify the KPI and the PPM, in order to discover talents. Using objective values simplifies the scientific analysis of the performance and consequently also the evaluation of the players. The higher differences between Armenian and European Leagues are in HI, MPHI, Acc and Dec parameters, respectively with a %Dec of 30,88%, 17,68%, 20,38%, and 26,21%. As the literature, shows the high-intensity events are the performance indicators of efficiency and of sport results, more correlated with the possibility of obtaining an advantage during matches.

The analyzes carried out in this Ph.D. thesis present numerous evaluations that can be summarized in:

- The Osgnach's MP approach results to be an invalid method in deriving the real internal load of the individual athletes because individual physiological differences make it impossible to accurately estimate the real energy expenditure of each individual with the simple use of a pre-built formula;
- Another critical point of the Osgnach's method is that it is based on the formulas of Minetti et al. (2001) which were derived from a study carried out on cross-country athletes, obviously, the PPM of this sport is very different and far from that of football;
- To detect the true energy expenditure provided by the aerobic mechanism during the course of the trainings or competitions, it will be necessary to integrate a respiratory rate sensor into the GPS shirts.

Obviously, the problem concerning the analysis of anaerobic and anaerobic energy consumption is still open;

- The MP approach result to be more near the real value of internal effort during the low-intensity runs and walking, more the intensity rise up, more the errors rate widens;
- The PPM analysis during training and matches result to be crucial to determinate the performance of teams and individual players, in order to create specific training dived by roles and characteristics. Using PPM could be easier to define talent and to divide players into levels. Of course, using GPS or performance video analysis is possible to detect only physical data that have to be correlated with technical and tactical, to better define the real abilities of footballers.

Acknowledgments

Here we are finally, at the end of this long course of study, started in the distant 2010, trying to retrace the footsteps of my myth of that time, Jose Mourinho, graduated in physical education, before starting his football career. I never liked too much to express my feelings with words either written or expressed orally; I generally prefer to express what I feel through my daily life gestures. However, never-mind this is the day…

Look at my past I cannot fail to mention the people who, together with my parents, have contributed to the formation of the man that I am now, my beloved grandparents. My grandfather was my first best friend and he made my childhood an unforgettable time. My grandmother, on the other hand, guided me during my adolescence and in my first years at university, a trusted confidant of a thousand thoughts and fears.

I have fewer memories of my paternal grandparents, unfortunately my grandfather died when my father was little while my grandmother spent only a few days with me, because she was living in her native country. In any case I have always felt her affection and her love transmitted through the repetition of some simple words in farsi “Ciro Jan Cubi ? Bie Iran... Kasghange Kasghange”.

What about my parents, it is difficult to find words… my mother is the person who taught me what love is and how to share it. My father, even if it is difficult to cohabit with his character, he is my pride; he showed me how a man should be in every days of his life.

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