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Functional analysis of soccer game

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ABSTRACT

The paper describes football performance indicators using functional analysis. We observed eight 2010 football World Cup games. Input data included distance run and running time for Serbian, Spanish, Dutch and German players. During the games, players from the three teams ran averagely 10.2±0.83 km and spent 1500 ±124.5 kcal. 53% of energy was produced by aerobic and 47% by anaerobic processes; their average aerobic energy power was 17.7±1.61 kcal/min, lactate 135 ±11.76 kcal/min, ATP alactate over 600 kcal/min and CP power over 400 kcal/min. Average speed run of 15±1.36 km/h in aerobic mode, and maximum speed of 24.84 km/h in lactate mode and maximum speed of 33.47 km/h in alactate mode. Serbian player ran 12.87 km and spent 1110 kcal. 20% of this energy was produced in anaerobic lactate mode with top running speed of 22.05 km/h and 80% of energy was produced in aerobic mode with running speed of 11.16 km/h. The average aerobic energy power was 12 kcal/min and lactate power was 70 kcal/min. Compared to the other national team players, he showed weaker energy efficiency: 26%-251%. According to the results, structure of energy production is a better indicator of performance in soccer than distance run.

Keywords: Energy production, aerobic energy, anaerobic lactic energy, anaerobic alactate energy, the structure of energy consumption.

INTRODUCTION

Mass use of modern hardware and software systems (AMISCO system) for monitoring and analysis [9]in soccer matches and training is recognized today worldwide. Generally, most users of such system monitor only structural analysis data [1, 2,14], such as the frequency and speed of implementation of offensive soccer tactics, frequency, distance and running speed with and without the ball, number and accuracy of passes, ball possession time, number of shots on goal, shots to goal ratio, number of lost balls, number of errors, crossings, interruptions in the offensive zone, corners and so on. Although functional analysis of soccer matches is not a novelty [11,15], software for mass use has not been developed yet. The current system is offers insufficiently functional information on the total distance covered by a player or the entire team during a match. Teams whose professional staffs work with analysts make comprehensive functional analysis of matches and trainings using videos. This paper discusses the problem of functional analysis from methodological and practical points of view [6] using as an example the stats of national team midfielders and offensive players from Serbia, Spain, the Netherlands and Germany. We analyzed the matches from the 2010 World Cup in South Africa. The data used in this paper come from the official website of FIFA and video recordings of the mentioned soccer matches. Also, a part of the data was collected from official websites of top European clubs. The aim of this paper is to stress the need for developing a software for wide use, as well as to point to the need and possibilities of using the results of functional analysis in programming [7,8, 9), training and performance improvement.

MATERIALS AND METHODS

The methodology of functional analysis for soccer matches

Equipment and other sources for data collection

Presently, experts generally use hardware and software systems for monitoring and analyzing soccer matches and training (AMISCO system used for game structure analysis in FIFA and UEFA competitions), as well as equipment for recording of the matches played. Also, they use the official websites of FIFA, UEFA and individual soccer teams. The outputs from a hardware-software system are quantitative, qualitative, original and derived kinematic, dynamic and functional information about the elements of soccer game. Videos allow subsequent analysis.

Sample of analyzed matches

We analyzed the quarterfinal, semifinal and final matches (7 matches total) played during the 2010 World Cup held in South Africa. In these games was analyzed energy efficiency of national teams from Spain, the Netherlands and Germany. At the same time we analyzed energy efficiency of a Serbian national team midfielder who played in Serbia-Australia match (group stage of the competition, group D). In that game the Serbian team ran 117 km, while Australian team ran 122 km. Australia won 2-1.

Sample of players

In the sample of midfielders and attackers from the national teams of Spain, the Netherlands and Germany, the average body weight was 74.86 ± 5.9 kg, while the Serbian player with the best energy productivity result weighed 76.0 kg.

Table 1. Indicators of functional performance in soccer

Group of variables	Variables or game statistics or performance indicators
Group 1	Total distance run; Distance run in the aerobic mode; Distance run in the anaerobic lactate mode; Distance run in the anaerobic alactate mode.
Group 2	Speed of running total distance; Speed of running in the anaerobic lactate mode; Speed of running u in the anaerobic alactate mode.
Group 3	Total energy spent; Energy spent in the aerobic mode; Energy spent in the anaerobic lactate mode; Energy spent in the anaerobic alactate mode; Speed of energy production in the aerobic mode; Speed of energy production in the lactate mode; Speed of energy production in the alactate mode.
Group 4	Body weight; % total energy; % lactat energy; % alactat energy; % aerobic work; % lactat work; % alactat work; % aerobic distance run; % anaerobic lactate distance run; % a anaerobic alactate distance run; % speeds of running.

Sample of variables

Basic data that were entered in the check list and from which we formed all the variables were the running times and distances ran by each team and each player from the sample during games. The main group of data includes the weight (kg) of soccer players. A part of the data was obtained using the AMISCO software. A part of data was taken from the official FIFA website (www.fifa.com). The rest of the data were collected from video analysis of the eight matches in question. The data on body weight of sample players were taken from the official websites of their clubs. The information about the distances, the running times and the players' body weight helped us calculate (Table 1) a group of variables such as the total distance ran (km) and distances ran in (km). The second group of calculated variables related to the speed of total distance ran (km/h) and speeds (km/h) for the distances ran in different running modes. The third group of variables consists of energy equivalents for running distances expressed in kcal and kcal/min. The fourth group of variables included body weight (kg), percentages calculated from comparisons of distance, speed and power.

Monitoring and analysis flow of the observed matches

Due to the different needs of the functional analyses, we observed different time intervals in the matches. First, we observed the entire matches (90 minutes) plus overtime when available. Afterwards, we broke the matches into smaller intervals: 0-15, 15-30, 30-45, 45-60, 60-75, 75-90 min, as well as overtime when available.

Methods of data analysis

For each player from the sample, we calculated the speed of running for individual distances using the distance covered and the time they took to cover the said distance. Based on the distance covered, time and body weight of players we calculated the work and speed of performance during work (power) using formulas ($A = G . s$) and ($P = A / t = Fv$). Body weight of each player was turned into strength using ($G = mg$) formula where g equals 9.81. The force was expressed as N ($kgms^{-2}$), the work in J ($Nm = m^2\ kgs^{-2}$) and the power in watts ($J / s = m^2\ kgs^{-3}$). Using the relations between work and energy we calculated the energy equivalents (kcal and kcal/min) of individual distances ran by each of the players [5,6]. Standard descriptive parameters were calculated for all the variables (mean, standard deviation, minimum, maximum and coefficient of variation).

RESULTS

Table 2. The results of monitored variables of the Serbian national team player

Variables	Results
Group 1	
Total distance run	12.87
Distance run in the aerobic mode	10.30
Distance run in the anaerobic lactate mode	2.574
Group 2	
Speed of running in the aerobic mode	11.16
Speed of running in the anaerobic lactate mode	22.05
Group 3	
Total energy spent	1110
Energy spent in the aerobic mode	887.9
Energy spent in the anaerobic lactate mode	221.8
Speed of energy production in the aerobic mode	11.00
Speed of energy production in the lactate mode	70.00
Group 4	
Body weight	76.00

The analysis of [5,6,7,8,9] the energy performance of the Serbian player (Table 2) is based on the data obtained from the match between Serbia Australia. In that match, the Serbian player ran a total distance of 12.87 km, with an average speed at 11.16 km/h. His running distance in lactate regime was 2.574 km with the maximum running speed at 22.05 km/h. That speed is also his maximum in lactate regime. The results of the analysis indicate that the Serbian player, in order to run the distance of 12.87 km, had to spend 1110 kcal of energy. In doing so, an average energy output (energy production speed) was at 12 kcal/min or at 0.16 kcal/min per kg of body weight. He ran most of the distance (10.296 km) in the aerobic regime spending 887.9 kcal energy (80%), while the rest (20%) of the distance (2.574 km) was covered the anaerobic lactate regime burning 221.8 kcal of energy and glycogen as the main energy source. His maximum speed of producing lactic energy (lactic power) during the game was 70 kcal/min. His maximum running speed was at the lower limit for lactate running speed regime when compared to the world's top soccer players [7,8,9]. The data shows that during the game he did not run in speeds pertaining to alactate mode and that he did not use the ATP and CP alactate anaerobic energy sources.

Table 3. Results of descriptive analysis of the monitored variables in Spanish, Dutch and German national team players

Variables	M	SD
Group 1		
Total distance run	10.2	0.83
Distance run in the aerobic mode	5.42	0.48
Distance run in the anaerobic lactate mode	3.80	0.34
Distance run in the anaerobic alactate mode	0.98	0.08
Group 2		
Speed of running in the aerobic mode	15.00	1.36
Speed of running in the anaerobic lactate mode	23.67	0.68
Speed of running in the anaerobic alactate mode	31.61	1.04
Group 3		
Total energy spent	1500	124.5
Energy spent in the aerobic mode	795.0	69.64
Energy spent i in the anaerobic lactate mode	555.4	4.44
Energy spent i in the anaerobic alactate mode	150.3	9.02
Speed of energy production in the aerobic mode	17.7	1.61
Speed of energy production in the lactate mode	135.0	11.76
Speed of energy production in the ATP mode	525.24	42.00
Speed of energy production in the CP mode	356.48	27.20
Group 4		
Body weight	74.86	5.9

The analysis of [6] the energy performances (Table 3) of Spanish, Dutch and German players are based on the matches played during the quarterfinals, semifinals and final matches. The Spanish, the Dutch and the Germans ran an average distance of 10.2 ± 0.83 km per game and spent more than 1500 ± 124.5 kcal of energy. In the lactate regime, they covered an average distance of 3.8 ± 0.338 km with 555.4 ± 4.44 kcal consumption. In the alactate regime, they covered an average distance of 0.98 ± 0.08 km consuming 150.3 kcal. In the aerobic regime, they covered an average distance of 5.42 ± 0.48 km burining 795 ± 69.64 kcal. The average aerobic energy was 17.7 ± 1.61 kcal/min or 0.23 kcal/min per kg of body weight with an average running speed at 15 ± 1.36 km/h. Their maximum running speed in lactate regime was at 24.84 km/h. Lactic energy production speed was at 135 ± 11.76 kcal/min. The maximum recorded running speed in alactate regime was at 33.47 km/h. The maximum energy production speed in ATP regime was 600 kcal/min, while in the CP regime it stood at 400 kcal/min.

DISCUSSION

When looking at the data of the overall distance covered by the Serbian player, we can conclude, based on the general acceptance the importance of this factor in the outcome of a game [1, 2], and considering that other players have less mileage, that his excellent energy and tactical results come from the distance covered and not from an outstanding energy production structure. In addition, we could say that his energy and tactical performance were equal or higher than those of most Spanish, Dutch or German players due to the fact that he covered more mileage. But when one performs a functional analysis [6,7, 11] of the matches and establishes the structure of energy production, one gets a completely different picture. According to the results of functional analysis the structure of the energy performance of the Serbian national team player were weaker than those of Spanish, Dutch or German players. Spanish, Dutch and German players covered 53% of the total distance in aerobic energy production regime, 37% in lactate regime and 10% in alactate regime, as opposed to the Serbian player who covered 80% of the distance in aerobic regime and only 20% in lactate regime. The interesting thing is that Russian midfielders in the seventies and eighties covered about 17 km per game [12] without leaving the aerobic regime, which resulted in annoying, inefficient and slow play of their players and teams. They regularly lost from foreign teams whose players ran 7 to 8 kilometers per game, because these teams covered 60% of the total distances at speeds that match anaerobic lactate and anaerobic ATP and CP alactate energy production regimes. By further comparing the results of functional analysis we can confirm that the Serbian national team player produced 26% less overall, 11% higher aerobic and 2.51 time less lactic energy than Spanish, Dutch or German players. The rate of aerobic energy production in Spanish, Dutch and German players was higher by 47.5%, while lactic energy production was higher by 51%. The Serbian player's running speed in aerobic mode was lower by 25%, and the running speed in lactate mode was lower by 12%, not to mention the running speed and energy production in the alactate regime, which Serbian player did not even entered during the whole game because of slow recovery after lactate efforts [5]. Spanish, Dutch and German players recover faster after alactate and lactate efforts, and therefore are more likely to run using those energy production modes. They had the highest frequency and running speed in these modes during the championship. The frequency of fast runs related to a considerable number of their functional characteristics and energy processes [15, 13], the speed of recovery during and between games [3, 7] and the model of training tailored to the creation of winning structure of energy production [7]. Their success was the result of dominant ball possession results in games, more frequent attacks on goal, more passing, more accurate passes from the other teams during the 2010 World Cup held in South Africa [www.fifa.com]. The ranking of the three teams at the 2010 World Cup in South Africa shows that the structure of energy production has an undoubtedly positive effect on the structural elements and the outcome of the game, and is much better as a performance indicator in soccer then the total distance covered.

Obvious confirmation of this is the ranking (23rd in the overall standings) and the quality of Serbian national team's performance [www.fifa.com]. When Serbian players were forced to change the structure of energy production during a game to anaerobic and high-speed energy production, because of the pace imposed by opposing teams, they started to experience fatigue relatively quickly. They began to run slower, make mistakes in the passes, while their reaction speed dropped. In addition, they displayed the following characteristics: intellectual disorientation, distortion of perception and deterioration of technique. They made mistakes and poorly controlled own movements – they committed fouls in harmless situations hitting an opponent not in the possession of the ball and missed easy and sure shots on the goal and lost the matches. Such behavior was caused by the very rapid exhaustion of their glycogen reserves in muscles [5,7], a drop in blood sugar levels below 50% of normal values, the accumulation of lactic acid in the muscles and central nervous system, reducing PH values in muscle fatigue of the nervous system, blocking the contractile machinery of muscles, causing poor intermuscular and intramuscular coordination [8]. The unfavorable energy production regime was caused by the insufficiently developed strength and energy production capacities [7]. This was enhanced through inadequate training mostly conducted in aerobic mode, deficiency of lactate-mode trainings and an almost negligible number of trainings in alactate mode. The inadequacy of training and the slow recovery after a season in Bundesliga clubs was stressed by Lames & Kolbinger [4] without giving fundamental reasons. This model of training, able to create players who can run for long time at low speeds during the game but who quickly tire when running at higher speeds, which requires lactate-alactate mode to produce energy, is wrong for current circumstances. In order to achieve an energy production that would lead to winning structure for all players, we must use the models of training which provide the combined regime [7].

Practical application of functional analysis results

The results of functional analysis indicate the energy production method that would lead to winning structure, as well as the training model appropriate for the said structure. The national teams able to burn 1600 kcal per match, while, at the same time, producing 46% of energy in anaerobic lactate regime, 14% in anaerobic alactate and 40% in aerobic regime, can expect outstanding results at the future European and World cups [7,8,9]. Players need to be trained to be able to [7,8] produce 736 kcal of lactic energy at the rate of between 115 kcal/min and 145 kcal/min and to be able to run at speeds ranging from 23.4 km/h to 24.84 km/h in this mode during a game. Then to produce 224 kcal of alactate energy [6,9] at the speed between 490 and 610 kcal/min which would allow them to run at speeds from 28 km/h to 34 km/h. Finally, the training has to enable them to create 640 kcal of aerobic energy at the speed from 16.5 kcal/min to 25 kcal/min, which would allow them to run at speeds ranging from 14 km/h to 19 km/h and a quick recovery regardless of the running mode [5,7,8,911]. In order for managers and teams to fully exploit their ingenuity, tactical knowledge and superiority in the preparation of matches, programming and training, they, among other things, must have at their disposal indicators of structural and functional analysis of the opponent's play [5,7,8,911]. In addition, they should take into consideration the preferred energy production that would lead them to the desired winning structure, as well as the energy potentials of players. Based on these data, they could program and control training and performances in matches. They should collect data during and after matches or training. Using modern hardware and software systems for monitoring, performing structural and functional analysis of matches and trainings would enable them to do this. All types of analysis performed through programming [1,7,9] and used by coaches should be handled by a highly trained analyst (programmer-methodologist) expert in modern software. Therefore, analysts should be a part of coaching staff.

CONCLUSION

Functional data analysis of soccer matches from the 2010 World Cup in indicate that the best teams' players during the matches run an average of 10.2 ± 0.83 km and burn 1500 ± 124.5 kcal of energy. 53% of the energy was produced in aerobic regime and 47% in anaerobic regime while their average energy production levels were at 17.7± 1.61 kcal/min in aerobic regime, 135 ± 11.76 kcal/min in lactate regime, maximum ATP production in alactate regime was at 600 kcal/min and CP force was at 400 kcal/min. Such production of energy in the world's best players allowed them to run in aerobic mode with average speeds at 15 ± 1.36 km/h; in the lactate regime their maximum speed was at 24.84 km/h, and 33.47 km/h in alactate regime. In comparison to foreign players, the Serbian player showed lower energy performance by 26%-251% even though he ran 12.87 km per match. Instead of using the total distance covered in order to evaluate the functional characteristics of the player's performance, we should use the data relating to the structure of running and the structure and speed of energy production. Furthermore, these results indicate the necessity of using functional analysis of matches performed using modern software for successful programming and control of training and performance in games, as well as the need for national teams' and clubs' staffs to hire highly trained analysts (programmer-methodologist).

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