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Original Article

External loading in football to discriminate the different performance model

FRANCESCA D'ELIA
Department of Human, Phylosophical and Educational Sciences, University of Salerno, ITALY

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Abstract
Purpose: External load analysis is one of the fundamental criteria in soccer, to more easily monitoring the team more easily both during the training phase and during the match itself, by analyzing the difference between the complete performance and performance to be reached. External load monitoring has been analyzed in several recent studies; however, research has mainly focused on professional soccer teams or also on non-professional ones, but without specifications for different study levels. The aim of this study has been to quantify measures and to evaluate and compare the differences among the non-professional players' load demands. **Methods:** Three non-professional Italian male soccer teams, D-Serie, 1st Category and Under-19, with a total of 30 players participated in this study. GPS was used to monitor the external load of a mid-season match. One-way ANOVA and a Bonferroni post-hoc have been used to analyze differences between groups. The significance level has been set at $P < 0.05$. **Results:** The results have shown statistically significant differences ($p < 0.05$) among the three teams in terms of distance ($p = 0.00$), power plays ($p = 0.02$), energy ($p = 0.00$), player load ($p = 0.00$), distance x minute ($p = 0.00$), power score ($p = 0.00$) and work ratio ($p = 0.00$). Overall, in terms of volume, the 1st Category team has performed better than the other two, while in terms of intensity, the better performing team has been the D-series team. **Conclusions:** Results should be applied to design training programs, to improve appropriately each team for external load demand profiles for the team and to know, in advance, the differences among the categories.
Keywords: monitoring; soccer; players; assessment; load; GPS

Introduction

In soccer, training and match monitoring are particularly attentive, so the assessment of the load imposed by training and matches is recognized as a fundamental task at any competitive level (Miguel et al., 2021, Mitrotasios, 2021). Soccer players must follow specific training methods in order to be able to cope with high physical demands required during the match, such as accelerations and decelerations, high speed, high intensity sprints and changes of direction, power, and so on (D'Elia et al., 2021, 2022, Aliberti et al., 2021, Mohr et al., 2005). These high-intensity movements can cause fatigue if repeated throughout the match (Altavilla, 2019, 2023). Therefore, training programs should aim to improve the fitness-related skills to tolerate and to repeat such high-intensity physical exercise, especially when combined with key tactical actions also in young footballer (Esposito et al., 2019). Consequently, external load analysis, as an objective quantification of the work done during training (about distance covered, number of acceleration and decelerations, max speed achieved, or metabolic power expressed), is one of the key parameters to be taken into account in order to monitor the player more easily both in training and during the match (Raiola, D'isanto, 2016), analyzing the difference between performance done and performance to reach (Lopez et al., 2014). In recent years, there is an increasing number of studies about the external loads of high-level soccer players during training (Malone et al., 2015; Kalapotharakos, 2021, González-Fernández, 2022). External load is a criterion characterized by those components that constitute the magnitude and intensity of stimuli, as well as the density, distance and frequency with which they are offered. In other words, it can be defined as the work completed by the soccer player during a training session or competition, measured independently of his internal characteristics. The skills related fitness to objectively quantify external load is essential in player monitoring (Borresen & Lambert, 2009) as it allows coaches to assess the effectiveness of their workouts, customizing them to meet the match requests (Martins, 2023). The components can be both quantitative (distance, volume, frequency, and complexity of the stimulus) and qualitative (intensity and density of the stimulus) (Altavilla et al., 2022, 2017). In non-professional football teams the external load has been, too often, generalized without specification referred to each different level. Instead, it should declare the different parameters to design properly the training program.

To quantify external load, an excellent tool is the Global Positioning System (GPS), whose first research applied to soccer has been carried out by Castagna et al. (2009), but has been subsequently increasingly used in a widespread ways and study (Izzo et al., 2020ab). GPS is a satellite positioning and navigation system that, through a dedicated network of orbiting artificial satellites, provides a mobile terminal or GPS receiver with

Corresponding Author: FRANCESCA D'ELIA, E-mail: fdelia@unisa.it

information about its geographic coordinates (Hofmann-Wellenhof et al., 2012). It allows to make a detailed assessment of the external load to which the athlete himself is subjected (D'Isanto, 2020, 2019).

External load is a parameter used in many recent studies (Castagna et al., 2017; Clemente et al., 2019; Oliva-Lozano et al., 2021) to monitor players; however, research has been focused primarily on professional teams (Gholizadeh et al., 2021; Reynolds et al., 2021). Studies targeting non-professional soccer players are lacking in the literature, as also stated by Sanchez-Sanchez et al. (2019) in his study. The reasons may be due to the lack of monitoring tools about non-professional teams and the high cost of GPS, which therefore limits the ability of some clubs to monitor external load in matches and training (Reynolds et al., 2021). Therefore, the purpose of this study has been to quantify and compare the match load requests of soccer players from three non-professional teams: D-Serie, 1st Category, and Under 19. Load analysis could help coaches and various clubs to better understand the differences among non-professional teams and thus design training programs to achieve long-term physical affects along the graduate application from the lowest to the highest category related physical demands.

Material & methods

Study design and participants

This is a report of an observational study, aimed at investigating the match load requests of non-professional Italian male soccer players. Convenience sampling method has been used to find participants.

Three non-professional Italian male soccer teams participated in the study: a D-series Team, composed by 10 players (28.6 ± 1.9 years old), an Under-19 Team (U19), composed by 10 players (18.7 ± 0.7 years old) and a 1st category (1st-C), composed by 10 players (25.2 ± 1.5 years old).

Goalkeepers were excluded from this study and only data of participants who played the match have been analyzed. Each player was instructed on the scope of the study, and an informed consent was obtained. The study was conducted according with the ethical standards of the Declaration of Helsinki of 2013.

Procedure/Instruments/Measure/

Data were collected during a mid-season match, using wearable GPS-devices (Catapult One) sampling at 10 Hz. This GPS unit tracks and improves key individual player metrics, including total distance, sprint distance, top speed, and more, analyze player positioning and access performance and trending data.

The external load parameters recruited have been about:

1. Volume metrics, such as:
- Total distance traveled in meters: distance traveled during a specified period of time;
- Sprint distance: instance accumulated during high-speed running/sprinting;
- Power Plays: significant action in which your power is greater than 20 watts per kilogram for more than one second;
- Energy (kcal): energy consumed during a game or training session;
- Impacts: number of large hits a player takes during a contact match;
- Player load: work done by the player during a training session or game;

2. Intensity metrics, such as:
- Maximum speed: maximum speed a player records during a given session;
- Distance per minute: general representation of how hard and intensely a player worked;
- Power score: intensity of training drills in which a high work rate is evident within a small area;
- Work ratio: amount of time a player is working versus resting (Catapult One).

Statistical analysis

Descriptive statistics are reported as M ± SD. After checking the normality of the data with the Shapiro-Wilk test ($p > 0.05$), a one-way ANOVA has been conducted for each dependent variable to assess differences between groups. In case of significance, a Post Hoc Bonferroni has been used to compare each group in turn. Significance has been set at $p < 0.05$. Data have been analyzed using SPSS (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY).

Results

The collected data about distance (Km), distance in sprint, powerplays, energy (Kcal), impacts, player load, distance per minute (m/m), power score (w/kg) and work ratio, collected during a single match played by the D-series Team, U19 Team and 1st-C Team are shown in Table 1.

Table 1. GPS parameters measured during the match of D-series, U19 and 1st-C.

GPS PARAMETERS	D-Series		U19		1st-C	
	M	SD	M	SD	M	SD
Distance (km)	6.15	1	5.3	1.52	8.37	0.98
D in sprint	540.19	183.58	402.21	161.37	565.39	216.42
Power plays	41	9.88	31.2	8.32	45.9	14.94
Energy (kcal)	776.02	123.13	637.57	179.88	1050.04	128.21

Impacts	2.9	2.76	2.5	3.06	3.1	1.91
Player load	281.7	48.42	266.09	83.02	404.06	55.28
Max speed	8.05	0.57	7.72	0.46	7.74	0.62
Distance per minute (m/m)	108.76	14.28	85.17	9.73	89.15	9.48
Power score (w/ kg)	8.81	1.33	6.81	0.79	7.02	0.86
Work ratio	46.78	9.92	31.06	6.33	34.45	4.91

From the one-way ANOVA, there were statistically significant differences ($p<0.05$) among the three teams in terms of distance ($F=17.57$; $p=0.00$), power plays ($F=4.30$; $p=0.024$), energy ($F=20.66$; $p=0.00$), player load ($F=13.93$; $p=0.00$), distance x minute ($F=12.30$, $p=0.00$), power score ($F=11.41$; $p=0.00$) and work ratio ($F=12.62$; $p=0.00$).

From the Bonferroni Post Hoc, which allows for a rolling comparison of the three teams, statistically significant differences emerged between:
- D-series and 1st-C ($p=0.001$) and U19 and 1st-C ($p=0.000$) in terms of distance (table 2);
- U19 and 1st -C ($p=0.023$) in terms of powerplays;
- D-series and 1st -C ($p=0.001$) and U19 and 1st -C ($p=0.000$) in terms of energy;
- D-series and 1st -C ($p=0.000$) and U19 and 1st -C ($p=0.001$) in terms of player load;
- D-series and U19 ($p=0.000$) and D-series and 1st -C ($p=0.002$) in terms of distance per minute;
- D-series and U19 ($p=0.001$) and D-series and 1st -C ($p=0.002$) in terms of power score;
- D-series and U19 ($p=0.000$) and D-series and 1st -C ($p=0.003$) in terms of work ratio.

A detailed description is shown in Table 2.

Table 2. Rolling comparisons of GPS parameters among the three teams.

Dependent variable	(I) Teams	(J) Teams	Sig.	Confidence interval 95%	
				Lower limit	Upper limit
Distance (km)	D-series	1st-C	0.001	-35.92	-0.859
	U19	1st-C	0.000	-44.39	-17.064
	1st-C	D-series	0.001	0.85	35.926
		U19	0.000	17.06	44.396
Powerplays	U19	1st-C	0.023	-277.23	-16.76
	1st-C	U19	0.023	16.76	277.23
Energy (kcal)	D-series	1st-C	0.001	-440.69	-107.34
	U19	1st-C	0.000	-579.14	-245.79
	1st-C	D-series	0.001	1.073.448	4.406.952
		U19	0.000	2.457.948	5.791.452
Playerload	D-series	1st-C	0.001	-195.44	-49.28
	U19	1st-C	0.000	-211.05	-64.89
	1st-C	D-series	0.001	49.28	195.44
		U19	0.000	64.89	211.05
Distance x minute (m/m)	D-series	U19	0.000	10.59	36.58
		1st-C	0.002	6.612	32.60
	U19	D-series	0.000	-36.58	-10.59
	1st-C	D-series	0.002	-32.60	-6.61
Power score (w/kg)	D-series	U19	0.001	0.82	31.71
		1st-C	0.002	0.61	29.57
	U19	D-series	0.001	-31.71	-0.82
	1st-C	D-series	0.002	-29.57	-0.61

Discussion

The purpose of this study has been to compare players' match load demands from D-series, 1st-C and U19 teams. Specifically, in terms of volume, the 1st -C team performed better than the other two, while in terms of intensity, the better performance has been by the D-series team. The differences between parameters have been analyzed to highlight the differences among teams.

Comparison among teams in the comparisons of volume measures

Starting with the volume measures, in terms of the **distance covered** parameter, the team that ran the most was the 1st -C team, followed by D-series and U19. The components that most affected the total distance covered in the game were the players' level of athletic condition, genetics and match tactics. The 1st -C had similar results as the D-series. The U19 had significantly lower results than the other two because the players were less organized tactically and inferior under the athletic parameter. In **sprint distance**, we noted that the difference among the three teams was not significant, although in first place we always found the 1st -C, followed by U19 and D-series. A higher amount of sprinting generally means a higher level of fitness in soccer

(Buchheit et al., 2010). In **powerplays**, there is no difference both between D-series and 1st-C, as well as between D-series and U19. Players were able to obtain a similar number of actions within this parameter. The actions counted within the powerplays stood for the players having high power consumption. In contrast, a statistically significant difference was found between 1st-C and U19, probably because the volume of Viribus' match performance had been larger. In the parameter of **energy** (kcal) that is consumed during a match, a statistically significant difference was found between 1st-C and both D-series/ U19. This could have been due to the fact that the energy parameter was closely related to the previous parameters, i.e. distance run, distance covered in sprints and intense actions. As a result, those who ran more and performed more intense actions consumed more calories. In **impacts**, which assess the aggressiveness of the match, no significant differences were found. This is not a very important parameter as far as player performance analysis is concerned. It is simply a figure related to the number of big hits a player takes during a contact match. In **player load** the difference was statistically significant between 1st-C and both D-series and U19. This parameter represents the work done by the player during the match. It is a measure of volume.

Cross-team comparisons in intensity measures

Turning to the intensity measures, in terms of the **max speed** parameter there was no difference among the three teams. However, in first place ranked the D-series, as a higher level team. Such peaks are not important because they may be isolated cases. In **distance x minute**, the difference was significant between the D-series and both 1st-C and U19, but not between the latter two. A professional soccer player covers about 100 /120 meters per minute during an official game. The D-series, being in a higher category, approached the parameters of professionals, unlike the other two teams. Regarding **power score** , the difference was statistically significant between D-series and both the other two teams, but not between them. Metabolic power is a parameter that calculates accelerations and decelerations (Coutts et al., 2015). More skillful players perform such actions faster and more efficiently. We note that in the D-series, this parameter was very high, which highlighted the difference between categories: it makes us understand why players in the higher category have a performance pattern with more intense peaks. Finally, regarding the **physical work index**, the difference was statistically significant between D-series and both the other two teams, but not between them.

Conclusions

This study has some limitations. Firstly, only one match and one team was analyzed for each category. This may limit the application of our results to other sports clubs. Furthermore, this study did not analyze the difference in external load parameters between roles, which is a very important factor to take into account. Future studies could focus on replicating the proposed idea by trying to fill these gaps, thus trying to expand the sample for each category, divide the players by position (Mancini, 2021) and analyze more games throughout the season. Despite that, the expectations of the observational study were met (Raiola, 2023). Results show us that in terms of intensity related to metabolic processes, the D-series team has performed significantly better than the other two teams. In terms of volume, on the other hand, the 1st -C, excelled compared to the other two. The latter, however, in addition to aerobic components, should focus on anaerobic components, which are useful in key situations for success in the game. Consequently, then 1st -C players could take part in a D-series championship with the right tactical arrangements and power-focused training. Players participating in the Junior Regional / U19 championship, at present, cannot take part in a D-series championship, but they should improve all athletic parameters beyond tactical and technical ones.

The U19 team could face a 1st-C championship, as anaerobic capacities do not differ significantly from each other, but they should improve in volume. These results could be used to design training programs in order to improve each team in terms of external load, to allow them to advance in category. Thanks to the monitoring of these parameters, it is possible to design training programs aimed at improving specific fitness parameters in football, according to the strengths and weaknesses, to make the athletes progress in the higher level categories. In this perspective, GPS is a very useful tool to understand in what respect teams need to improve and to understand what kind of training to administer. The goal of any coach is to get his or her players to a higher level so that they will be considered by higher ranked, and, perhaps, professional clubs.

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