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Equation for player load control of training with GPS in a high-performance soccer
Ecuación para el control de la carga de entrenamiento con datos de GPS en fútbol de alto rendimiento

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Abstract. Background: load management during competition and training is essential to achieve maximum performance in soccer players while also helping to reduce the risk of injury. External load is determined by the relationship between volume and intensity. Volume is the overall amount of effort exerted in an activity, whereas intensity describes the level of effort per unit of action or time. Objective: to analyse the variables proposed in an equation for controlling the external load and the variations that occur depending on the selection of their reference values. Subjects: nineteen high-level U23 soccer players (22.5 ± 1.8 years). Method: A total of 77 records from 11 official matches on the Olympic circuit were analysed. The external load was calculated from volume and intensity values based on the parameters total distance (TD), distance at high intensities (HID), number of accelerations and decelerations (AcDc) and number of sprints (Nsp). Factors of equation estimated from general and individual references were compared. Results: The calculation of the total external load using general values was significantly lower than with individual values (73.7±16.5 vs. 82.4±13.5), as was the volume (71.5±15 .6 vs. 81.6±13.4) and intensity (74.8±17.2 vs. 81.8±13.5). Conclusions: important differences were observed depending on the reference values considered. General values may be optimal when aiming to raise the group level and compare players, but individualization of the reference values is essential for the correct control and adjustment of the training load.
Key words: soccer training, sprint, external load, load monitoring.

Resumen. Introducción: el control de la carga durante la competición y el entrenamiento se hace imprescindible para alcanzar el máximo rendimiento en futbolistas, ayudando a disminuir el riesgo de lesión. La carga externa está determinada por la relación entre volumen e intensidad. El volumen es el total de esfuerzos realizados en una actividad y la intensidad es el nivel de esfuerzos por unidad de tiempo. Objetivo: analizar las variables propuestas en una ecuación para el control de la carga externa y las variaciones que se producen en función de la selección de sus valores de referencia. Sujetos: diecinueve jugadores sub23 de alto nivel (22,5 ± 1,8 años). Método: Se analizaron un total 77 registros de 11 partidos oficiales del circuito olímpico. La carga externa fue calculada con valores de volumen e intensidad en base a los parámetros distancia total (TD), distancia a altas intensidades (HID), número de aceleraciones y deceleraciones (AcDc) y número de esprints (Nsp). Los factores de la ecuación con referencias generales e individuales fueron comparados. Resultados: El cálculo de la carga externa total a partir de valores generales fue significativamente menor que con valores individuales (73,7±16,5 vs. 82,4±13,5), al igual que el volumen (71,5±15,6 vs. 81,6±13,4) y la intensidad (74,8±17,2 vs. 81,8±13,5). *Conclusiones*: se observaron importantes diferencias en función de los valores de referencia considerados. Los valores generales pueden ser óptimos a la hora de querer subir el nivel grupal y comparar jugadores, pero la individualización es imprescindible para el correcto control y ajuste de las cargas.
Palabras claves: Entrenamiento de fútbol, sprint, carga externa, monitorización de la carga.

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Introduction

Soccer is an open-team-sport of interactions in shared space that requires complex neuromuscular, metabolic, and physical demands. These demands must be developed so that the team can achieve maximum performance in competition. Thus, during training is possible to perform planned technical-tactical exercises that optimally impact these capabilities. In this sense, the need arises of controlling the external training load (relation volume/intensity) during sessions with the aim of planning this training load and reducing the risk of injuries (Gabbett, 2016; Zurutuza et al., 2017).

Technology provides the possibility of using GPS. These devices offer real movement data on the field to quantify the total external load. The number of variables that allow the GPS to be used is very broad and is constantly being developed by sports scientists (Oliverira & Brito, 2023).

Many studies have focused their attention on the analysis of the external load using different metrics. In relation to distances, speed thresholds and acceleration, the names are varied, as are the reference values (Gualtieri et al., 2023; Miguel et al., 2021). Sanchez-Sanchez et al. (2019) used as variables: i) training duration, ii) distance covered, iii) distance covered between 14.4 – 19.8 $km \cdot h^{-1}$ (high-intensity distance), iv) sprint distance (>19.8 $km \cdot h^{-1}$); v) high acceleration covered distance (>2.5 $m \cdot s^{-2}$) and deceleration (< -2.5 $m \cdot s^{-2}$). In a similar manner, Clemente, Owen, et al. (2019) and Clemente, Seerden, et al. (2019) used as thresholds (14.0–20.0 $km \cdot h^{-1}$) for running distance, and (>20.0 $km \cdot h^{-1}$) for the sprint distance.

Additionally, as proposed by Hernández et al. (2021), this variables can be considered relatively (m/min) depending on the participation time of each player during the training session: i) total relative distance ($m \cdot min^{-1}$), ii) sprint distance (> 19.8 $km \cdot h^{-1}$,$m \cdot min^{-1}$), iii) high-speed distance (14.4-19.8 $km \cdot h^{-1}$, $m \cdot min^{-1}$), iv) medium-speed distance (7.00-14.4 $km \cdot h^{-1}$, $m \cdot min^{-1}$), and v) number of accelerations (> 3.0 $m \cdot s^{-2}$, $num \cdot min^{-1}$). In this case, the external load for each analyzed variable corresponded with the average value of the sessions of the same orientation that configures each one of the analyzed micro-cycles.

On the other hand, Owen et al. (2017) and Djaoui et al. (2022) propose to relate four variables for the follow up of the external load: Total distance covered (TDC), High-speed-running >19.9 km·h^{-1} (HSR), Sprint Distance > 25.2 km·h^{-1} (SPD) y total number of high intensity accelerations and decelerations > 2 m·s^{-2} and < - 2 m·s-2 (Sum HIE) and these related to the effective time.

In other studies, changes in direction at high intensity that are also found recorded from accelerations and decelerations above 2.5 m·s^{-2} and below -2.5 m·s^{-2} respectively (Vasquez Bonilla et al., 2023).

Regarding reference values, different works have recorded routs per match between 10,000 and 12,000 m of total distance (Aquino et al., 2021; Owen, 2019). Also, distances greater than 2200 m have been reported for values above 14.4 km·h^{-1} (Diez et al., 2021); at 1050 m above 18.0-19.8 km·h^{-1} (Aquino et al., 2021); and 543 m over 19,8 km·h^{-1} (Djaoui et al., 2022).

In other matters, Owen (2019) in his multi-mechanical model approach considers one equation for volume and another for intensity. In both cases, using GPS data, the total distance and the distance covered at high intensity are included as key performance indicators to assess the locomotor impact, while the distance covered in sprint and the sum of high intensity accelerations and decelerations inform about mechanical impact. This equation has been discussed due to the collinearity of some variables (Weaving & Read, 2022), although it is very practical and useful for the daily work of analysis and training planning (Owen, 2022).

From this base equation, some variations are possible (Owen, 2022). There are still possibilities for adjustments and adaptations to different contexts and needs. For example, elements can be introduced into the discussion such as the quantification of references to be able to transform into relative values (Bradley, 2024). Also, the maximum absolute values achieved by a player or team in several previous matches can be considered; a value obtained from a percentile or group data (P90, P95, P99, etc.); even arbitrary maximum reference values. In this way, the maximum values that act as divisors in the percentages of the observed variables are obtained.

Giving the importance of load control to general adequate adaptations in training and its prominent role when selecting and defining tasks, the objective of the study was to analyze the proposed variables in an equation for control of the external load and the variations that occur depending on the selection of its reference values.

Method

Subjects

Nineteen players from the Honduras under 23 team (4 centre-back, 3 right/left-back, 4 right/left-midfield, 6 centre-midfield, 2 centre forward) with an average age of 22.5 ± 1.8 years were part of the study. A total of 77 records from 11 official matches (4 Pre-Olympic Tournament, 4 Pan American Games, 3 Olympic Games) were analyzed. To consider their data, the inclusion criteria were established to have played at least 85 minutes per match and not present deficiencies in GPS data collection.

Procedure

To calculate the total volume of a training match, the following variables are considered from Owens et al. (2019): a) TD: Total Distance covered in meters; b) HID: distance covered at high intensities (>15 km/h); c) AcDc: number of accelerations (>2,5 m/s^2) and decelerations (<2,5 m/s^2); d) Nsp: number of sprints (>24 km/h). Equation 1 shows the variables that are divided by their maximum reference values.

$$Volume = \frac{\frac{TD}{TD\_max}x100 + \frac{HID}{HID\_max}x100 + \frac{AcDc}{AcDc\_max}x100 + \frac{Nsp}{Nsp\_max}\ x100}{4}$$

Equation 1. Calculation of the total volume of the external load

In the case of intensity, the previous variables are calculated as an average per minute based on the time played by each footballer. In this way, the variables considered are: a) TD_min: total distance covered per minute in meters; b) HID_min: distance covered at high intensities (>15 km/h) per minute; c) AcDc_min: number of accelerations (>2,5 m/s^2) and decelerations per minute (<2,5 m/s^2); d) Nsp_min: number of sprints (>24 km/h) per minute; e) Time played by athlete in minutes. The values obtained from the average per minute are considered based on the time played by each athlete (equation 2).

$$Intensity = \frac{\frac{TD\_min}{TD\_min\_max}x100 + \frac{HID\_min}{HID\_min\_max}x100 + \frac{AcDc\_min}{AcDc\_min\_max}x100 + \frac{Nsp\_min}{Nsp\_min\_max}\ x100}{4}$$

Equation 2. Calculation of the intensity of the external load.

Finally, the total load is considered as the average between volume and intensity. In the case of intensity, it is relative to the time played and 95 minutes, which is an arbitrary value obtained from the approximate duration of the matches (equation 3).

$$\text{Total match load} = \frac{\text{Volume} + \frac{\text{Intensity x Time played}}{95}}{2}$$

Equation 3. Calculation of the total match load that integrates volume and intensity.

The study followed the premises of the Declaration of Helsinki and had the players' consent to the Honduras Soccer Federation (FFH) for the use of the data for research purposes. This study was approved by the Ethics Committee of Higher Institute of Physical Education, University of the Republic, Uruguay (Number 8/2021).

Statistical analysis

A description of the results is made using the mean and standard deviation (SD), as well as the minimum (min), val-

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ues and the 25th (25%), 50th (50%) and 75th (75%) percentiles. Furthermore, for the comparison of the groups using the non-parametric Wilcoson test, reporting significant differences for $p < .05$; and the effect size through the biserial rank correlation (ES) with the following assessment (irrelevant < 0.1; small 0.1; medium 0.3 y large 0.5) (Goss-Sampson, 2019). The calculations are performed using Pandas Python library and the JASP statistical package.

Results

The average duration of matches that ended in regulation time was 97.4 ± 2.0 and a median of 98.0 minutes. Table 1 describes the minimum, maximum, average and deviation values of the different observed variables.

Table 1.
Results observed with GPS for the different variables analyzed.

	n	Average	SD	minimum	25%	50%	75%	maximun
TD (m)	77	9289	1319	6463	8515	9271	9980	12870
HID (m)	77	1722	507	906	1372	1645	2085	2939
AccDcc	77	83	21	32	67	80	95	139
Nsp	77	9.1	4.9	1.0	5.0	9.0	11.0	23.0
TD_min (m/min)	77	96	14	65	87	97	103	130
HID_min (m/min)	77	18	5	9	14	17	22	31
AccDcc_min	77	0.85	0.22	0.34	0.71	0.84	0.97	1.46
Nsp_min	77	0.09	0.05	0.01	0.05	0.09	0.12	0.24

TD - Total distance; HID - High intensity distance; AcDc - Number of accelerations and decelerations; Nsp - Number of sprints; min – minute; SD – Standard deviation.

Table 2 shows the comparison between the values obtained from general and individualized reference values.

Table 2.
Comparison between the factors of equation calculated from general and individual references

General references	Average	SD	Individual references	Average	SD	wilconxon	p	ES
Match load	73.7	16.5	Indiv. Match load	82.4	13.5	423	< .001*	0.13
Volume	71.5	15.6	Indiv . Volume	81.6	13.4	279	< .001*	0.13
Intensity	74.8	17.2	Indiv . Intensity	81.8	13.5	621	< .001*	0.13
Volume (TD)	84.4	12.0	Indiv . Volume. (TD)	91.5	8.4	427	< .001*	0.13
Volume (HID)	86.1	25.3	Indiv. Volume. (HID)	81.6	17.4	1938	0.03*	0.13
Volume (AcDc)	69.9	17.5	Indiv. Volume. (AcDc)	83.4	14.6	282	< .001*	0.13
Volume (Nsp)	45.4	24.4	Indiv. Volume. (Nsp)	69.7	24.9	71	< .001*	0.13
Intensity (TD)	87.5	12.7	Indiv. Intensity. (TD)	92.3	8.9	652	< .001*	0.13
Intensity (HID)	81.1	23.9	Indiv. Intensity. (HID)	82.4	17.3	1400	0.61	0.13
Intensity (AcDc)	62.6	33.8	Indiv. Intensity. (AcDc)	70.1	24.9	162	< .001*	0.13
Intensity (Nsp)	67.9	17.1	Indiv. Intensity (Nsp)	82.7	15.0	877	0.01*	0.13

* Significant differences for $p < .05$; SD: standard deviation; ES: effect size.
TD - Total distance; HID - High intensity distance; AcDc - Number of accelerations and decelerations; Nsp - Number of sprints; SD – Standard deviation.

Figure 1 shows the relationship between the match load calculation using general absolute references and individualized references. The adjustment $r = 0.68$ ($p < .001$).

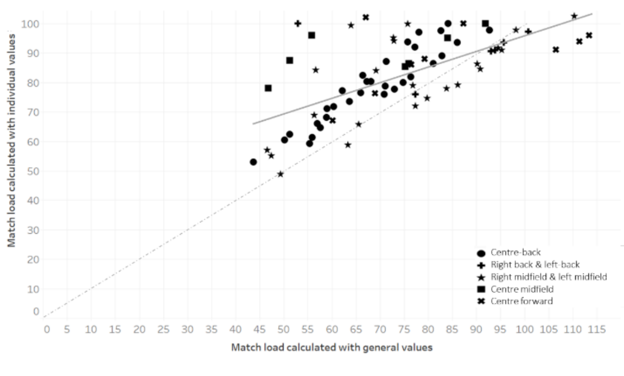

Figure 1. Relationship between match load calculated with general and individualized values. The straight line shows the correlation with $r = 0.68$. The dotted line is the perfect correlation.

Discussion

The objective of the study was to analyze the variables proposed in an equation for the control of the external load and the variations that occur depending on the selection of their reference values. Based on the multi-mechanical model (Owen, 2019), equation 3 proposes an integration volume and intensity into a single index. In this case, it is generated from the average of the volume and intensity equations, although the intensity is previously divided by 95, which is an arbitrary value that arises from the average duration of a match. In this way, players who do not complete a match, as well as tasks and training exercises with variable durations can be compared based on a single index in relation to match load. In any case, we must highlight the practical value and its great usefulness for the real management of training (Owen, 2022).

On the other hand, incorporating sprint distance or sprint number into an equation that assesses external load should be discussed. Although sprint distance is a highly used variable by some authors (Owen, 2019; Owen, et al., 2017), some weaknesses can be discussed, such as for example, that the distance is already included in other factors of the equation such as high intensity distance and total distance (Weaving & Read, 2022). On the other hand, from a mechanical point of view, the main effort is focused on exceeding the sprint threshold, and not so much on maintaining the effort over a greater distance (Haugen et al., 2019; Mero et al., 1992). On the contrary, considering the number of sprints exclusively highlights the number of efforts made, and is more suited to the dynamics generated in football, where the majority of sprints are less than 30 m (Baptista et al., 2018). Furthermore, greater value is attributed to muscular and neural factors involved in the first seconds of repeated sprint actions (Bishop et al., 2011; Girard et al., 2011). In these moments, expressions of horizontal force and power are key (Samozino et al., 2022). In this way, the equation would have two factors linked to the metabolic aspects and two to the mechanical aspects.

Regarding the reference values for the equation, it is common to use general values for each variable that arise from the different research backgrounds and to a lesser extent individualized values (Gualtieri et al., 2023; Núñez-Sánchez et al., 2017; Zurutuza et al., 2017). In this sense, in Table 2 there are significant differences in the results of the load equation when the reference values were taken generally with respect to those taken individually. In our case, it was observed that the general values clearly underestimated the total external load, this difference being greater in relation to volume than intensity.

Regarding the volume components, considering general values underestimates the total distance, the positive and negative accelerations, and to a greater extent the number of sprints. On the contrary, an overestimation of the distance covered at high intensity is observed. We found that, for this level of competition, the reference values are overestimated for some players (Figure 1).

Furthermore, the general values are conditioned by two aspects that must be considered because of the latest FIFA regulatory modifications (2018): the total playing time and the number of substitutions. For one thing, actual playtime has increased. In this case, it was observed that the average playing time was 98 minutes, due to the incorporation of the VAR and the guidelines to the referees regarding overtime times, etc. This implies a constant review since it conditions the intensity values.

On the other hand, the increase in the number of changes, going from three to five, has resulted in a lower number of players completing the game. Moreover, tactically these players tend to be defensive center-backs to a greater extent. In this sense, differences by position have been reported that clearly show how the values of the distances covered vary (Bradley, 2014; Velásquez-González et al., 2023), which means that, as seen in figure 3, the general references for all players underestimate the efforts of the left and right defenders and overestimate the centre midfielders. Therefore, although absolute values can be used to make comparisons between players, it is essential to individualize references to adjust training loads (Gualtieri et al., 2023).

Finally, more research is necessary to determine the suitability of both the parameter taken to assess the load and their reference values, such as, for example, the number of previous matches considered, competition contexts and tactical proposals. The results of this study were obtained with U23 soccer players, which limits the generalization of the findings to athletes with different characteristics.

Conclusion

The possibility of integrating the volume and intensity parameters into a single external load index allows a simple evaluation of the effort made by a player in competition, regardless of the time they have participated. In addition, it is a very useful tool for planning training loads. On the other hand, important differences have been observed depending on the reference values considered. In this sense, the general values may be optimal when wanting to raise the group level and compare players, but the individualization of the reference values is essential for the correct control and adjustment of the training load.

Practical applications

The use of a single match load index (equation 3) that integrates volume and intensity has great practical value for performance monitoring and training prescription. When planning the load of training sessions, it allows controlling the demands of the different tasks on each athlete. Furthermore, the possibility of individualizing the total load, volume and intensity values is a highly useful tool to impact the planned aspects with greater accuracy.

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