BARÇA INNOVATION HUB
Universitas

# SELECTING VARIABLES: ARE WE REPEATING INFORMATION OR PROVIDING ADDITIONAL INFORMATION?

## RELATIONSHIP BETWEEN EXTERNAL LOAD VARIABLES

## 2.1 Interpretation of the relationship between variables

The large number of variables contributed by the technological tools available nowadays have made it necessary to study and reduce the number of variables to be managed in the training process. That is why we must choose the most valid options available in order to understand the demands of the sports activity in question. Selecting a set of variables (Halson, 2014) to quantify the external and internal load is the best alternative, but it is also the hardest; in order for this arduous recording process to be sustainable, the time, material, human, and technological resources available must be addressed. In this respect, it is preferable to analyze fewer variables and/or indicators and to study them in greater depth. Having a wide range (for example, 30 variables for 25 players over 300 sessions, representing 225,000 data points) which only describes the activity that was performed is not effective. If the information collected is not used for correcting deficiencies or reorienting content for the next session, microcycle or period, then the effort will be worthless. It should be more than a simple description; results should be recorded in order to assess and subsequently intervene.

# 2.2 Relationship between external load variables in complete training sessions

The number of variables and indicators that might be considered to quantify the load or the intensity of the tasks and sessions is very high. Nevertheless, in line with Halson's proposal (2014), we must try to include as large a variety of dimensions as possible. Managing these variables and indicators will make it possible to better understand the activity carried out by the athlete and thus make accurate decisions on the training loads and/or competition loads in the future.

## 2.2.1 Relationship with the Indicators Obtained from Accelerometry

We believe that it is important to dedicate a special section to the use of triaxial accelerometers of 100 Hz or more (embedded within GPS devices), which record accelerations produced in the three movement planes (axial, sagittal, and transverse). These systems have been validated for measuring physical activity demands in team sports (Boy et al., 2011), and have an advantage over other quantification methods used in intermittent sports since they consider exertions such as jumps, tackles, and other activities which are different from just running: in other words, actions that are common in team sports. This aspect acquires vital importance during open activities,1 since high intensity demands could be underestimated if the athletes' accelerations are not analyzed (Varley et al., 2011).

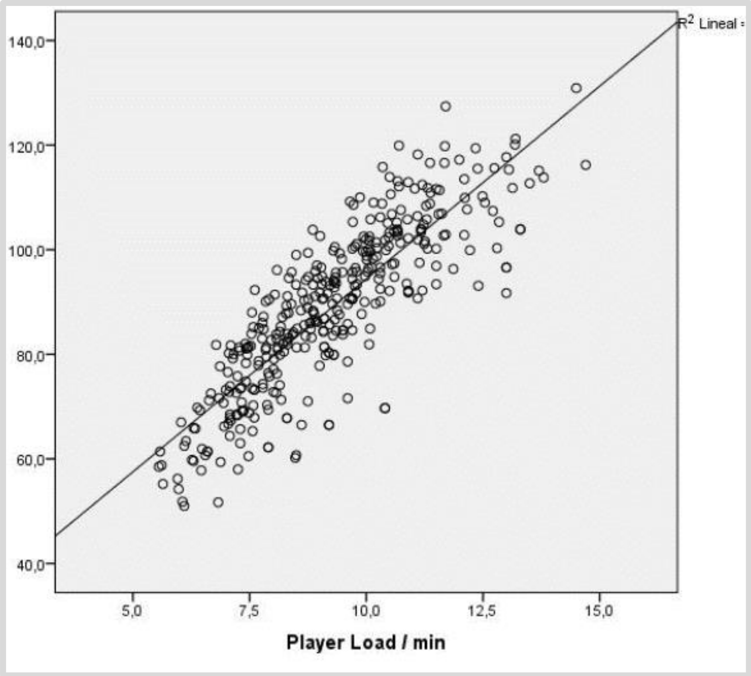
In soccer, Casamichana et al. (2012), used GPS technology (MinimaxX, v.4.02) to describe the physical profile of semi-professional athletes during friendly matches, and to understand the differences between positions. The GPS model

[1] In this context, some studies have used accelerometry in team sports such as rugby (Johnston et al., 2012; Cunniffe et al., 2009), basketball (Montgomery et al., 2010), and soccer (Casamichana et al., 2012), and it was introduced as a variable which was sensitive to changes in game situations, for example during training or competition, between different positions, and during different training tasks (Cunniffe et al., 2009; Montgomery et al., 2010). It also obtained high correlations with physiological indicators such as heart rate or lactate concentration (Montgomery et al., 2010).
[2] Catapult Innovations, Melbourne, Australia.

used in this study allows for the quantification of the training load through the player load (PL) indicator obtained through accelerometry. The analysis of the variable showed that those players with higher PL values are wide and center midfielders, thus suggesting that this indicator is sensitive to the "player position" variable. Given the importance of quantifying the training load in high performance athletes, these authors studied the validity of the PL indicator obtained through accelerometers within the GPS devices that were used (MinimaxX v.4.0), in accordance with the correlations made with other methods used for quantifying the load in team sports (Edwards' TL and RPE). The results showed significant correlations between the PL value and the Edwards method (r=0.70, p<0.01) and the session-RPE method (r=0.74, p<0.01), suggesting that the indicator obtained through accelerometry could be considered a good indicator for quantifying the load during full soccer training sessions.

A study by the same authors (as yet unpublished) of 700 records of full soccer sessions, also led to estimations of very high correlations between the distance covered per minute of practice and the player load·min-1 (Figure 2.1).

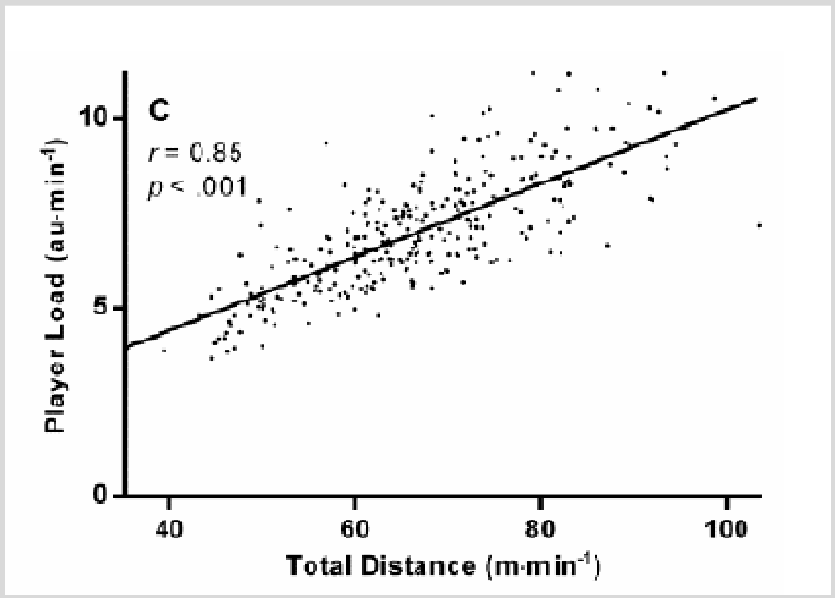
**Figure 2.1: Correlation between m·min$^{-1}$ and player load·min$^{-1}$ (obtained through accelerometry) during full training sessions**




Note: The relationship has been obtained from variables of intensity and not load, since they are expressed relative to the minute of practice.
Source: Castellano & Casamichana (2016).

Likewise, in his doctoral thesis carried out on professional English soccer, Akenhead (2004) found highly significant relationships between the distance covered and the player load (r=0.85; p<0.01), mainly due to the accelerations produced by running to the vertical axis (Fig. 2.2).

**Figure 2.2. Correlation between m·min$^{-1}$ and player load·min$^{-1}$ (obtained through accelerometry) during full training sessions**

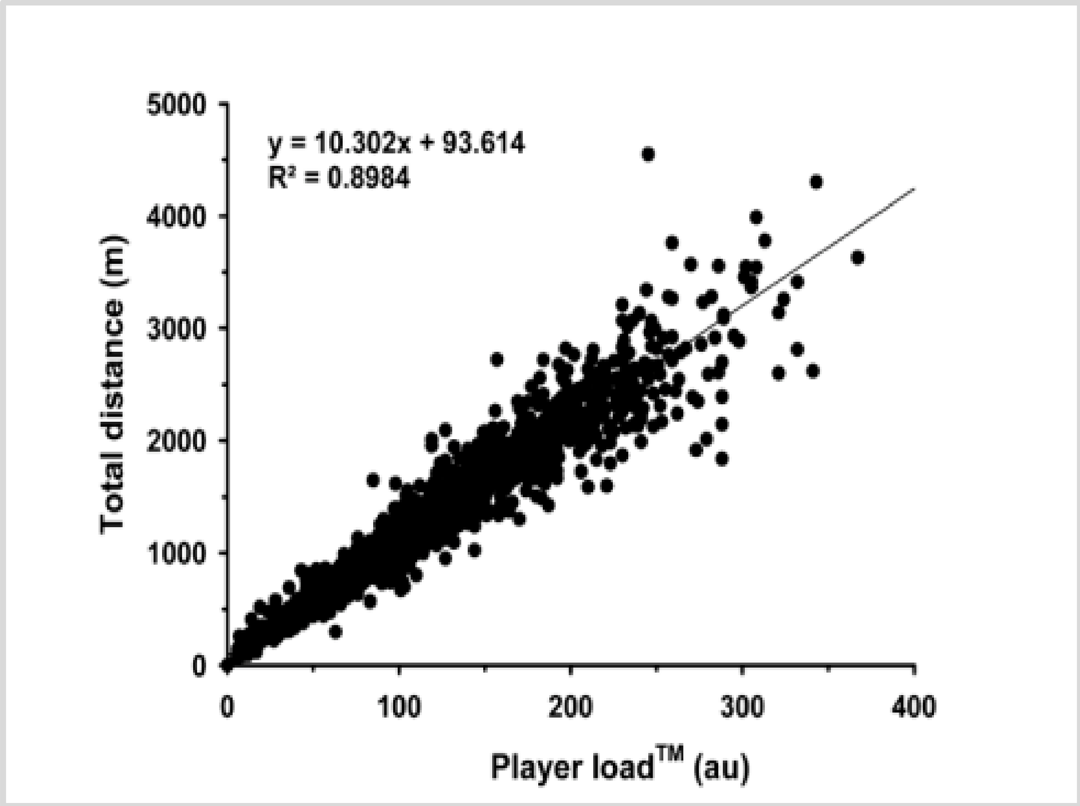



Source: Akenhead (2004).

Aughey (2011) found very high correlations between player load and total distance covered in Australian soccer players (Fig. 3.3). The determination coefficient indicates that the variance shared between both metrics is very high, so we would be able to estimate one value simply by knowing the other, with a relatively small margin of error.

Also, these important relationships lead us to question the need to incorporate both variables into the evaluation process in isolation, since they do not provide complementary information. Another issue includes the indicators that will be calculated by relating different variables, for example, using ratios such as the one obtained by dividing the player load by the distance covered, and this will be looked at in more detail later.

**Figure 2.3. Relationship between total distance covered and player load indicator obtained through accelerometry in Australian soccer players**




Source: Aughey & Boyd (as cited in Aughey, 2011).

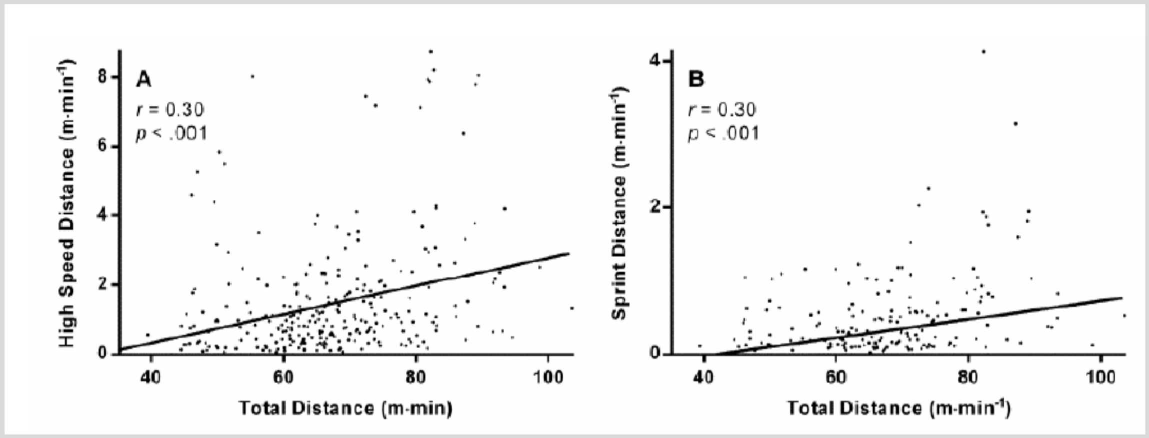
Gómez-Piriz et. al (2011) analyzed the validity of the total body load index obtained with another GPS model (GPSports, V1.23) which considers accelerations in all three planes of movement, sharing it with the RPE-sessions in elite players, and observed that this indicator was not a valid parameter for quantifying the workload in soccer, since it did not correlate strongly with the RPE and they did not register any variation in the position during small sided games. The authors claim that the value of the total body load provided by this GPS model could ignore the way in which the player moves or acts with the ball, which involve greater physiological impact (Reilly and Ball, 1984; Reilly and Bowen, 1984), unlike methods based on HR or the RPE which did make it possible to asses these aspects (Foster, 1998; Foster et al., 1995 and Impellizzeri et al., 2004).

[3] Team AMS. Canberra, Australian Capital Territory, Australia

## 2.2.2 Relationship between the Distances Covered at Different Speeds

Perhaps the first study to analyze in greater depth the relationship between the distance covered at different speeds was by Akenhead (2004), who found that the distance covered at high speed or at a sprint had a weak relationship with the total distance covered (r=0.30; p<0.01; Fig. 3.4).

**Figure 2.4. Relationship between total distance covered and distance covered at high speed (Figure A) and distance covered at sprint speed (Figure B), stated in m·min-1, during full training sessions**




Source: Akenhead (2004).

However, a recent study by Casamichana et al. (under revision) shows how the relationship between the total distance covered and the distances covered at high speeds decreases as the range of speeds used in categorizing the actions increases (Table 2.1). Thus the magnitude of the relationship between the total distance covered and the distance covered at a sprint (→ 20 km·h-1) is less than the relationship between the total distance covered and the distance covered at high speed (>16 km·h-1) in professional soccer players.

**Table 21. Pearson correlation matrix for each external load variable studied during full training sessions and soccer matches**

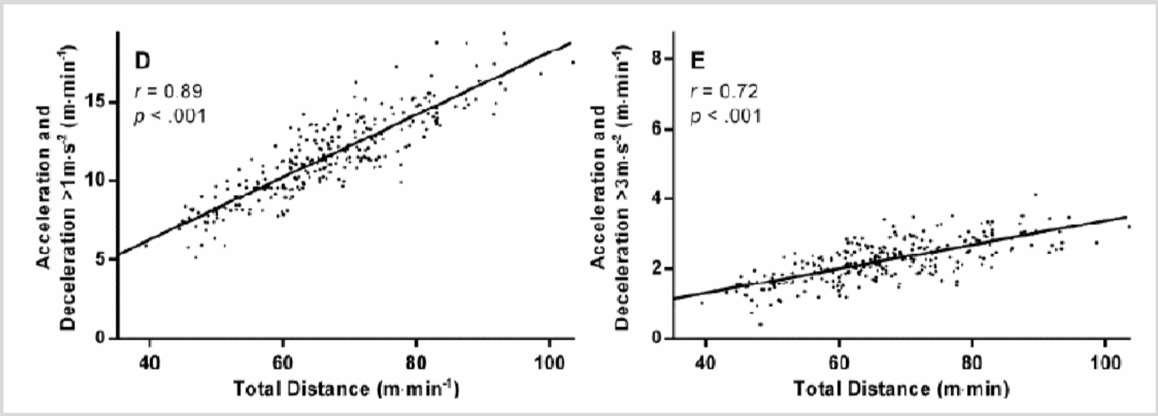
| | Variables | HSD | MPHID | HIAD | HIDD | Sprint D |
|---|---|---|---|---|---|---|
| All | Distance | 0.637l* | 0.865** | 0.887** | 0.868** | 0.438** |
| | HSD | | 0.899** | 0.576** | 0.583** | 0.895** |
| | MPHID | | | 0.808** | 0.817** | 0.701** |
| | HIAD | | | | 0.980** | 0.412** |
| | HIDD | | | | | 0.419** |
| | | | | | | |

Note: All correlations show a significance level of p<0.001. * significance p<0.001 and ** significance p<0.0001. HSD: high speed distance (>16 km·h-1); MPHID: metabolic power high intensity distance (→20 watt·kg-1); HIAD: high intensity acceleration distance (→2 m·s-2); and, HIDD: high intensity deceleration distance (←-2 m·s-2); SprintD: sprint distance (→ 20 km·h-1).
Source: Casamichana et al. (under review).

## 2.2.3 Relationship with Accelerations and Decelerations

In his doctoral thesis (2004), Akenhead proved that the distance covered has a strong relationship with the accelerations and decelerations made at low (r=0.89; p<0.01) and high intensity (r=0.72; p<0.01). 3.5).

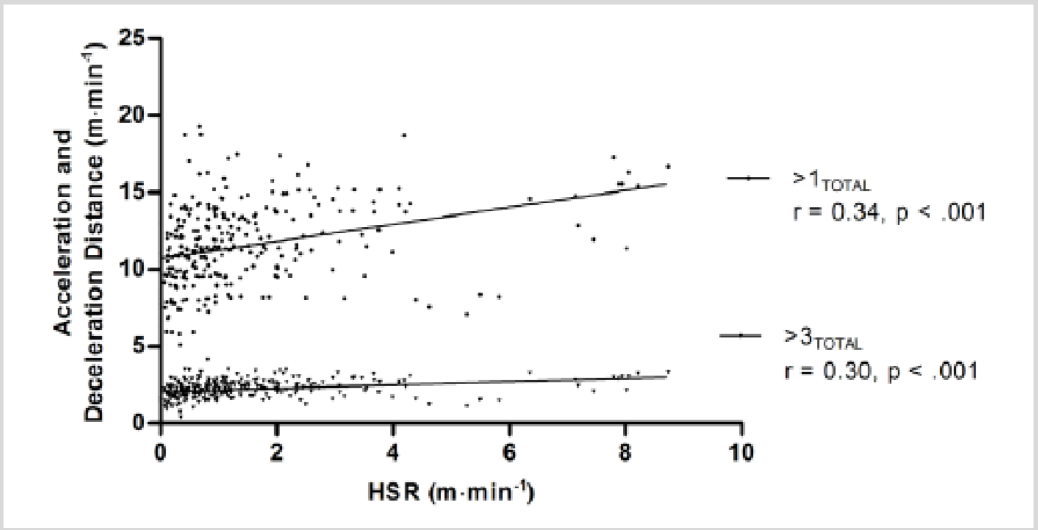
**Figure 2.5. Relationship between the distance covered during acceleration and deceleration at low intensity (Figure A), and the distance covered during acceleration and deceleration at high intensity (Figure B): all distances stated in m·min-1, during full training sessions.**




Note: All distances are stated in m·min-1 during full training sessions.
Source: Akenhead (2004)

However, as is the case when we try to relate distance covered to actions performed at high speed, the magnitude of the relationships diminishes as the acceleration and deceleration intensity increases (Fig. 2.6).

**Figure 2.6. Relationship between the distance covered at high speed (HSR) and the distance covered during low intensity acceleration and deceleration (>1 m·s-2), and with the distance covered during high intensity acceleration and deceleration (>3 m·s-2)**



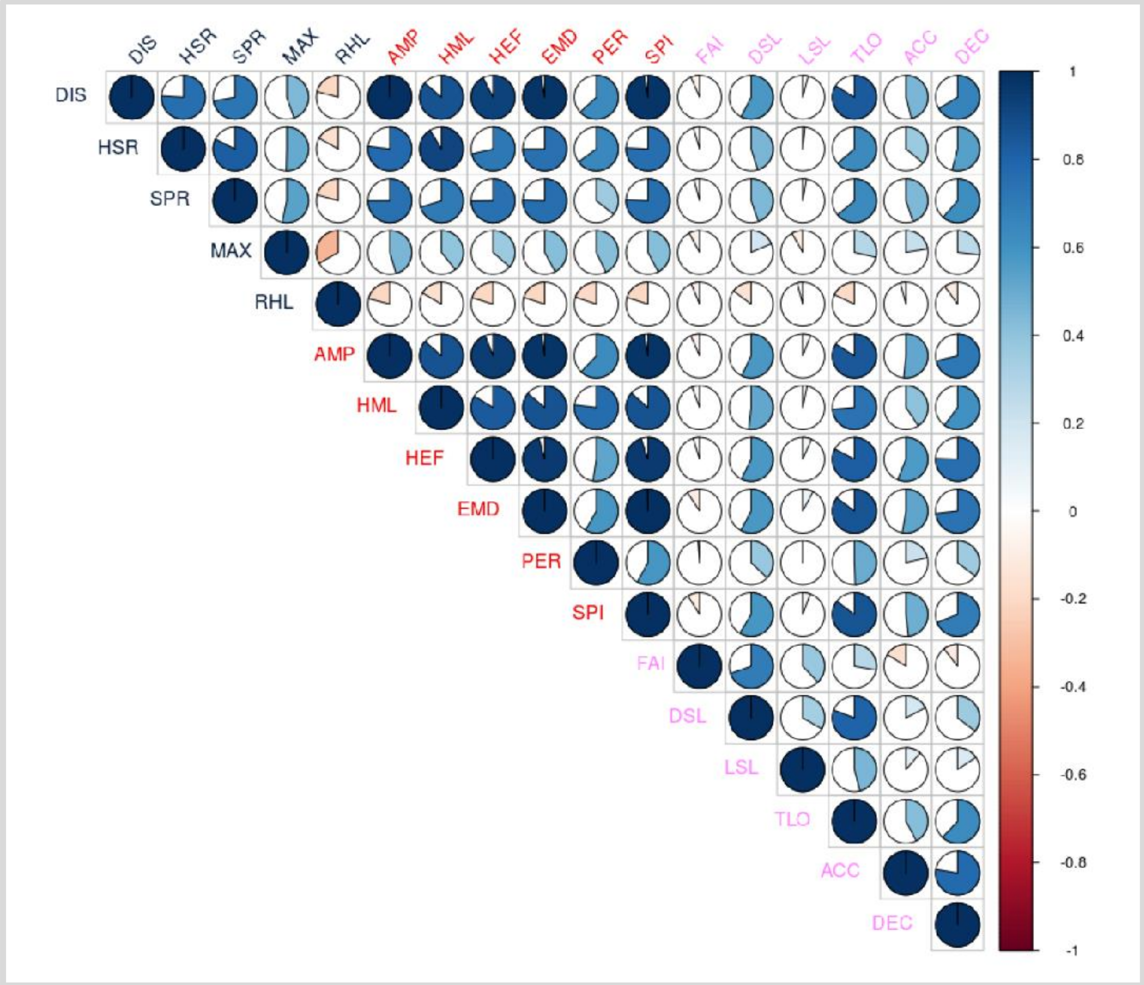

Note: All distances are stated in m·min-1 during full training sessions.
Source: Akenhead (2004).

### 2.2.4 Relationship between Different Variables

A very recent study by FC Barcelona assessed the relationship between 17 different variables obtained using a GPS device with multiple sensors. The authors divided the variables into 3 groups: locomotor variables, metabolic variables, and mechanical variables. The following statements emerge from their analysis (Figure 2.7):

- The relationships between variables in the same group are of a greater magnitude;
- The metabolic variables tend to relate very highly to each other, especially the average metabolic power (AMP), which includes a lot of information;
- There is a trend towards a medium-high correlation between locomotor variables, and poor correlation between mechanical variables;
- The fatigue index does not correlate with any measurement, with the exception of the dynamic stress load (DSL) which is used to calculate it.

**Figure 2.7. Graphic matrix showing the correlation between different variables used while monitoring training load**




Note: The name of the locomotive variables is colored gray, the metabolic variables are red, and the mechanical variables are purple. DIS is distance covered; HSR is distance at high-speed; SPR is sprint distance; MAX is maximum speed; RHL is high/low speed ratio; AMP is average metabolic power; HML is distance at high metabolic power; HEF are high metabolic power efforts; EMD is equivalent metabolic distance; PER is load percentage; SPI is speed intensity; FAI is fatigue index; DSL is dynamic stress load; LSL is lower speed loading; TLO is total loading; ACC is number of high intensity accelerations; DES is number of high intensity decelerations.
Source: Fernandez (2017)

The principal component analysis (PCA) has been applied to the study of variables in the world of sports. This analysis makes it possible to determine the principal components in a large series of variables, thus reducing the number of variables or components to understand.

Also, the position that each of the variables occupies within the different components also provides information on the degree of representation within each component. Casamichana et al. (under review) analyzed the PCA at different external load variables based on the training session, and obtained the following practical applications:

1) The type of training must be considered when deciding the training load values. This means that the variables which provide the most information during one type of session are different from the significant variables during another type of session, meaning that the analysis of different variables must be prioritized depending on the type of session or its content;
2) For training session -3, it seems that the training values could be interchangeable since there is one single component;
3) For all the sessions, session -4, session -1, and session +1, a combination of load values associated with strength and speed must be considered;
4) In sessions -4, +1 and in friendly matches, variables related to strength (high intensity accelerations and decelerations) are the ones that gain most prominence;
5) In session -1, the variables related to efforts made at high speed gain more prominence;
6) Metabolic power is always in an intermediate position, providing for both component 1 and component 2, but without becoming the principal variable in any of those components. We are therefore looking at a load indicator that "condenses" or "unites" information derived from different types of indicators.

# 2.3 Relationship between External Load Variables in Training Tasks

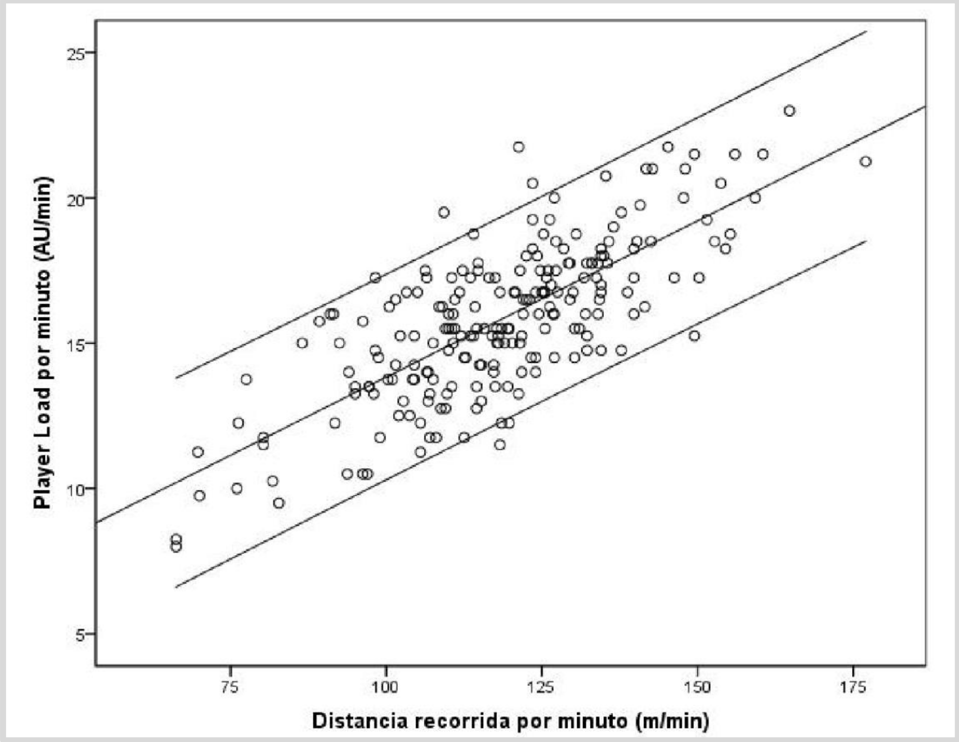
## 2.3.1 Relationship with the Indicators Obtained from Accelerometry

In soccer, the player load indicator obtained using accelerometry has been used to compare small sided games with friendly matches or different types of small sided games. When compared to matches, the player load value was greater during small sided games, as with other physical load variables studied during the research (distance covered·min-1 and work:rest ratio), except for maximum speed reached (Vmax), which was greater during the matches (Casamichana el al. 2012).

With respect to small sided games, the player load parameter was used to compare different workload systems (the same total workload duration but distributed in continuously, with only one repetition, and intermittently, where total duration is fragmented into different repetitions) (Casamichana et al. 2012), or by adjusting spatial orientation and the number of players (Castellano et al. 2012). No significant differences were found when the training system or the number of players are considered, and when the player load is reduced when the space is oriented using goals (the game objective is to score more goals than the opposing team), compared to when there are no set objectives and the task is carried out with the purpose of keeping possession of the ball.

The study by Casamichana & Castellano (2015) showed a significantly high relationship between player load and distance covered per minute ($r=0.75$, $p<0.001$) and a weak correlation with the load indicator obtained by using a rating of perceived exertion ($r=0.22$, $p<0.001$) (Figure 2.8). Based on these results, we can see a strong connection between the load indicator obtained through accelerometry (player load) and the total distance covered in training tasks; to evaluate the demands of the task, one of the variables could be ignored since we know that the greater the distance covered·min-1, the higher the player load·min-1 value will be, and vice versa.

**Figure 2.8. Relationship between player load per minute (UA·min1) obtained through accelerometry (%) and distance covered per minute (m·min-1) in different situations during small sided soccer games**




Source: Casamichana & Castellano (2015).

## 2.3.2 Relationship between the Distances Covered at Different Speeds

We will describe some of the aspects of these correlations for different formats of small sided games that we consider interesting (Table 2.2):

- The total distance covered only correlates with the distance covered at high speed in the 7v7 and 3v3 formats.
- The magnitude of the relationship between total distance covered is higher in lower speed categories (>18.0 km·h$^{-1}$) in relation to sprint efforts (>21.0 km·h$^{-1}$).
- In some cases, the relationship is inverse (negative), but without being statistically significant (and with non-existent or weak magnitude). Examples of such a relationship can be seen between the load indicator obtained through accelerometry (player load) and the frequency of sprint

efforts (FSS) in 5v5 and 3v3 formats. It therefore seems that when the player does a lot of activity during the tasks (representing a higher player load value), the frequency of sprints reduces, while in lower activity tasks players do a higher number of sprints.

- The relationships between distances and efforts at high velocity (>18.0 km·h[-1]) and at sprint (>21.0 km·h[-1]) are high or very high.

**Table 2.2. Relationship quantified using Pearson's correlation between different internal and external load variables in 7 vs. 7, 5 vs. 5 and 3 vs. 3**

| SSG | Variable | RPE | %HRmean | TD | PL | DSS | DHS | FSS |
|---|---|---|---|---|---|---|---|---|
| | %HRmean | .449** | | | | | | |
| | TD | .237* | .267* | | | | | |
| | PL | .184 | .138 | .836** | | | | |
| 7:7 | DSS | .098 | .13 | .081 | .041 | | | |
| | DHS | .125 | .208 | .320** | .235* | .741** | | |
| | FSS | .065 | .101 | .053 | .049 | .903** | .729** | |
| | FHS | .076 | .083 | .099 | .073 | .799** | .766** | .908** |
| | %HRmean | .601** | | | | | | |
| | TD | .371** | .597** | | | | | |
| | PL | .444** | .652** | .819** | | | | |
| 5:5 | DSS | -.094 | -.028 | -.163 | -.115 | | | |
| | DHS | -.073 | .134 | .021 | -.016 | .699** | | |
| | FSS | -.045 | .042 | -.162 | -.104 | .906** | .684** | |
| | FHS | -.008 | .129 | -.076 | -.072 | .832** | .741** | .909** |
| | %HRmean | .381** | | | | | | |
| | TD | .194 | .373** | | | | | |
| | PL | .053 | .361** | .783** | | | | |
| 3:3 | DSS | .236 | -.132 | .109 | .056 | | | |
| | DHS | .129 | -.032 | .295* | .107 | .565** | | |
| | FSS | .169 | -.143 | .087 | .020 | .814** | .457** | |
| | FHS | .225 | -.167 | .051 | -.036 | .898** | .571** | .868** |

Note: RPE means Rate of Perceived Exertion; %HRmean means Mean heart rate stated as a percentage of individual maximum; TD means total distance covered; PL means load obtained through accelerometry; DSS means distance at sprint speed; FSS means frequency of efforts at sprint speed; and FHS means frequency of efforts at high speed.
Source: Casamichana & Castellano (2015).

### 2.3.3 Relationship with Accelerations and Decelerations

To date, there have been no publications that relate efforts made during acceleration and deceleration at different velocity ranges with the relationship with other external load values during training tasks. However, this type of study is necessary for narrowing value selections, because of the huge amount of information currently available.

The relationship between different external load variables therefore provides us with interesting information to consider during the evaluation process of the soccer player, because in order to ensure the sustainability and efficiency of the process, the number or variables to be analyzed should be low. It seems that there are certain variables with a high degree of association, which would justify using only one of them, since the rest would somehow be represented by the chosen variable during the analysis process. Examples of this type of relationship have been observed between the load indicator obtained through accelerometry (player load) and the total distance covered. On the other hand, some variables show low level relationships, or even inverse relationships, which could justify the evaluation of both values. The distance covered and the distance covered at sprint speed could be an example of this type of relationship. Finally, it should be noted that depending on the type of session or task analyzed, the variables that will provide more information about the activity performed are different, and this aspect should be considered by the trainers.

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