MAUGHAN, P., SWINTON, P. and MACFARLANE, N. 2021. Relationships between training load variables in professional youth football players. *International journal of sports medicine* [online], 42(7), pages 624-629. Available from: https://doi.org/10.1055/a-1300-2959

Relationships between training load variables in professional youth football players.

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2021

Title: Relationships Between Training Load Variables in Professional Youth Football Players

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Abstract

This study aims to investigate the relationship between subjective and external measures of load in professional youth football players, whilst accounting for the effect of training theme or competition. Data from ratings of perceived exertion, and global positioning system derived measures of external training load were collected from 20 professional youth players (Age = 17.4 ± 1.3yrs) across a 46-week season. General characteristics of training sessions were categorised based on their proximity to match day. Underlying structure of the data were investigated with principal component analysis. An extraction criterion comprising eigenvalues > 1 was used to identify which components to retain. Three components were retained for training performed three days prior to match day (80.2% of variance), with two components (72.9 to 89.7% of variance) retained for all other modes. Generally, the first component was represented by measures of volume (Total Distance, PlayerLoad and low intensity running) whilst the second and third components were characterised by measures of intensity. Identification of multiple components indicate that load monitoring should comprise multiple variables. Additionally, differences in underlying structure across training days that reflected different goals, suggests that effective monitoring should be specific to the demands of different session types.

Introduction

Load monitoring is common practice in elite sport where coaches and practitioners prescribe and adjust training to maximise performance and reduce injury risk [1]. Load monitoring is seen as a complex and vital aspect of preparing team sport athletes that engage in a wide range of training activities and are required to perform near maximum capacity frequently during the competitive season. Survey research conducted in professional football identified that load monitoring is widely used [2]. The survey [2] identified that a wide range of load measures were collected, with monitoring practices generally tracking physical work completed by the player (characterised as external load), alongside monitoring the physiological response (characterised as internal load) [3].

Due to the lack of a gold standard measure of load, the majority of research studies have simply investigated the validity of measures of load against other available measures [4]. However, there are many complexities that have been identified with regards to load measurement including the multifactorial nature of the physiological response, and divergent individual response in terms of absolute values and the relationship between external and internal values. Additionally, the relationship between internal and external load metrics has been shown to alter based on the mode of training, providing an additional consideration for practitioners [5]. Alexiou and Coutts [6] with women football players reported a range of correlation coefficients between sRPE and Bannister's TRIMP of 0.74, 0.49, 0.61, 0.68 and 0.25 for sessions classified as conditioning, matches, speed, technical and resistance, respectively. A similar range of correlation coefficients demonstrating different relationships with training types were also presented for Lucia's TRIMP (0.34 - 0.75) and Edward's summated HR scores method (0.52 - 0.82) [6].

Given findings of previous research demonstrating divergence of metrics across different training contexts, it has been suggested that training load measures used individually or in combination, should be analysed based on the training theme [5]. Using five variables to quantify load, the authors' first assessed the underlying structure of relationships between measures during rugby league training via correlation analysis and principal component analysis (PCA) [5]. Sessions were categorised as small-sided games, conditioning, skills, speed, strongman and wrestle, PCA was performed to reduce the dimensionality of the dataset. Using this technique, more than one principal component for four of the six training themes (skills, speed, wrestle, and strongman training) was identified. They also found that for these modes of training, the component loadings for each of the load variables appeared to order themselves into groups of internal or external measures [5]. Furthermore, the mode of training appeared to affect whether the first principal component, that explains the most variance, loaded towards internal or external measures.

Further assessment of training practices in professional rugby league revealed the potential for multiple and contrasting components for different training types [7]. Using the same PCA techniques as implemented in their previous study [5], the authors assessed the underlying structure of load measures for sessions categorised as skills and conditioning, identifying one principal component (56.6 % of variance) for the skills sessions and two principal components (combined 85.4% of variance) for the conditioning sessions. In the original analysis only one principal component which explained 51.8% of the variance in conditioning training was retained [5]. Collectively, the research by Weaving and colleagues [5, 7] demonstrate that multiple measures are likely required to appropriately characterise the load experienced by team sport athletes.

The use and successful implementation of 'tactical periodisation' has led to increased interest in its use in professional football [8]. Planning sessions in this way also allows specific outcomes to be targeted, with specific physical, technical and tactical aims alternated through a training week. It has also been suggested that planning using this method may minimise fatigue accumulation, as focussing on a given quality may allow other physical qualities to recover. [9]. It is likely that the training methodology employed will be largely influenced by senior coaches, however, if training days were categorised targeting specific outcomes, then it would be beneficial for practitioners to select load measures to reflect objectives. The aim of the current study was to quantify and describe relationships between sRPE and external measures of load in football players across sessions with different characteristics. The study incorporated analysis methods previously used to assess underlying structure of the relationships between variables and their ability to summarise the response [5, 7]. Increased knowledge in the context of football will support practitioners by evidencing a process to support the selection of variables to monitor when training has a planned outcome.

Methods

Participants

Twenty male professional youth footballers (age 17.4 ± 1.3 yrs, height 178.0 ± 8.1 cm, mass 71.8 ± 7.2kg) were recruited during the 2018/19 season. Participants comprised multiple positions, with data collected from goalkeepers removed from the final analyses. Data recorded from a small selection of non-representative training sessions were removed to limit the influence of outliers [10]. Only data recorded from team training (defined as sessions comprising both starting and non-starting players) were included in the analysis, with post-match training for non-starters (top-ups), rehabilitation training and non-pitch-based sessions such as gym-based recovery or resistance training sessions excluded. . Sessions in the lead up to a match, alongside match play recordings were assessed. Sessions which took place in the days succeeding a match (i.e. MD+1/MD+2) or those that were not considered to be in preparation for a match, were discounted. The secondary data analysis nature of this study met ethical standards as described by Harriss et al. [11].

Procedures

RPE was collected, in isolation, approximately 30 minutes after each training session using a scale previously used with football players [12, 13]. All players had previous experience using the scale. Each RPE score was multiplied by session duration to obtain subjective training load [14]. Players wore commercially available GPS Units (Optimeye X4, Catapult Sports, Melbourne, Australia, Firmware version 7.27) previously used in research conducted in team sports [7, 15, 16]. The units included a GPS receiver and a triaxial accelerometer collecting data at 10 Hz and 100 Hz, with velocity and acceleration dwell times set at 0.6 s and 0.4 s, respectively. Each player wore the same device for each session [17]. Data were downloaded and analysed via the software package Openfield (Software version 1.19, Catapult Sports, Melbourne, Australia). Average satellite count was 10.7 ± 1.7 , the average horizontal distribution of position (HDOP) was 0.8 ± 0.2. Variables selected to quantify external load were total distance (m); PlayerLoad (au); low intensity running (< 14.4 $km.h^{-1}$, m), running (19.8 - 24.98 $km.h^{-1}$, m); sprinting (> 24.98 $km.h^{-1}$, m); accelerations (>2 $m.s^{-2}$ count); and decelerations (<-2 $m.s^{-2}$, count).

Statistical Analysis

Where data were missing, these were treated as missing at random and imputed using the MICE package [18]. Relationships between sRPE and external training load measures were quantified for each training day using Pearson's product moment correlation. Training and match load data were prepared for PCA by visually inspecting the correlation matrix to assess the factorability of the dataset

[19]. PCA was performed on the correlation matrix of variables as metrics were on different scales. The suitability of data were then assessed using Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and the Bartlett test of sphericity [20]. KMO (~chi-square) values were: 0.84 (10018), 0.75 (7443), 0.69 (2689), 0.77 (4236), and 0.72 (2205) for MD, MD-1, MD-2, MD-3 and MD-4, respectively. All tests of sphericity were significant ($p<0.001$). A KMO value of 0.5 or above has previously been identified as a suitable result to perform PCA [21, 22], and has been used in similar research [5, 7]. Principal components with an eigenvalue >1 were retained for extraction [22]. Briefly, an eigenvalue is a measure of how much variance there is in the data, therefore the component with the highest eigenvalue will be that which explains the majority of variance. When two or more principal components were retained based on their eigenvalue, varimax rotation was performed. For each retained principal component, only the original load variables with a principal component loading of >0.7 were retained [21]. All analysis was carried out in the statistical environment R (R Foundation for Statistical Computing, Vienna, Austria, version 3.6.2).

Results

There were 2827 individual recordings included in the analysis, comprising of 696 MD recordings and 2131 training session recordings. Distribution of the mean training loads for match play and each training day are presented in Table 1. Results demonstrated that mean values for duration and all load variables were highest on MD and lowest on MD-1. MD-3 was characterised by higher mean values for external load variables in comparison to MD-2 and MD-4.

Correlations including 95% confidence intervals for match-play and training are presented in Figure 1. Total Distance, PlayerLoad and LI.Running showed large to very-large correlations with sRPE. High-Speed Running showed small to large correlations, whilst Sprint Distance showed trivial to moderate correlations. Finally, accelerations showed moderate correlations, whilst decelerations showed small to large correlations with sRPE.

Results of the PCA are presented in Table 2. Two principal components were identified for MD, MD-1, MD-3 and MD-4, whilst three principal components were identified for MD-2. Variance explained and loadings are presented for the components following varimax rotation. The components explained 89.72%, 71.31%, 80.02%, 74.15% and 72.86% of the variance for MD, MD-1, MD-2, MD-3 and MD-4 respectively.

Figure 1 about here

Discussion

The main findings of the current study are the identification of multiple components in training days in the lead up to, and including, match play which differ across training day. This suggests that univariate assessments of load are insufficient when characterising the load experienced by players in training and match play. These findings are similar to those reported in professional rugby league players [5, 7]. Whilst match-play and three of the four training days produced two components; MD-2 identified three principal components. Analysis of the components revealed clear structures. Where two components were extracted these showed that the first component was generally characterised by measures of training volume (Total Distance, PlayerLoad and LI.Running). The second component was characterised by measures of intensity (Running, Sprinting, Accelerations and Decelerations). Where three components were extracted, these followed a similar pattern, but the intensity measures were split with accelerations and decelerations present in the second component and running and sprinting within the third component. Where sRPE was present within the components, it loaded in component one as a volume-based measure.

The findings of the present study coincide with those generated in professional rugby league players [5, 7] demonstrating that a single training load measure is unable to capture the variance of multiple measures across different training themes. This has further implications for practitioners when investigating load response relationship with performance or injury, as a multivariate analysis may provide more clarity than univariate assessments [7, 23] All training days analysed in the present study produced 2 or 3 principal components explaining 71.3% to 89.7% of the cumulative variance. As with previous findings the component loadings appeared to reflect either training volume or intensity [5]. In the present study during match play the highest loadings for component one were sRPE (0.89), total distance (0.94), PlayerLoad (0.91) and LI.Running (0.96). Conversely, for component two the highest loadings were for Running (0.72), Sprinting (0.94) and accelerations (0.77). Weaving et al. [7] in their second study of professional rugby league players showed that variables that loaded in the first component alternated between measures of internal or external training load. In the present study only a single measure of internal load was collected and therefore we were unable to assess the reproducibility of this pattern.

The finding of two or three components is key as it suggests, as proposed by Weaving et al. [5, 7], that the use of 1 load measure will be unable to capture the complexity of the training response. Their finding that the PCA results were linked to the type of training session provides further support for the use of multiple training measurements to characterise training response in team sport players [7]. Selection of training load variables, and the methods used will affect the outcome of any dimension reduction technique such as PCA and potentially limit comparisons that can be made between studies [7]. Initially Weaving et al. [5] used an arbitrary threshold of >15km.h^{-1} to assess high speed distance, which was then unable to account for additional variance during conditioning training. In their follow up study they assigned high-speed distance thresholds individually based on results from a 30 - 15 Intermittent Fitness Test. They suggested this is a potential reason for the extraction of a second principal component for training categorised as conditioning, which was heavily loaded by high-speed distance and explained a further 29.4% of the variance. This individualisation, alongside systematic selection of load variables that have been shown to identify a dose-response relationship with training outcomes such as changes in fitness or performance [24-26] is likely to lead to a more effective multivariate training load assessment model. These findings highlight opportunities for collaborations between researchers and practitioners to best determine procedures for selection of metrics, as well as methods of feedback specific to training modes. To achieve this the variables selected should be related to outcomes of injury, or changes in performance [7]. Whilst assessing the relationship between load and performance or injury was out with the scope of this article, it does appear that to assess training volume sRPE could be used in combination with either total distance, PlayerLoad or LI.Running. Whilst assessing intensity alongside this may be achieved by assessing running or sprinting distance.

A limitation of the current study includes categorisation of training based on proximity to MD rather than classifying sessions. This was done because football training sessions are generally categorised based on proximity to MD. However, categorisation of individual training sessions may lead to different results and linking these to more specific training themes could provide practitioners with information to aid training prescription and monitoring. If a day was categorised by larger pitch areas it is likely that alongside more total distance covered, practitioners may also identify higher values of running and sprinting activity. Conversely on days involving smaller-pitch sizes it may be that acceleration and deceleration efforts are more prevalent. Additionally, we did not account for the effect of starters vs non-starters in the analysis. Finally, practitioners should consider the reproducibility of this analysis within their own environments given we used data from a single team. Future research may also wish to include further analysis using internal load markers such as training impulse (TRIMP) to provide a broader understanding of the relationship between internal and external measures of load. Additionally, future research may also wish to include some reference to the prescribed load for players to give reference to relationships between actual load performed and programmed load. To conclude, the current study provides further evidence that a single measure of training load is not sufficient to assess the load experienced by players in training and match play.

Clearer categorisation of training themes, relative to match play, may provide greater insight to practitioners and improve monitoring practices and feedback of information. Future research using football players and potentially investigating labelling using different methods of categorising training sessions is required.

Table 1 – Mean (± SD) duration and training load measures across match play and training sessions

	Duration (mins)	sRPE (au)	Total Distance (m)	PlayerLoad (au)	LI.Running (m)	Running (m)	Sprinting (m)	Accel (count)	Decel (count)
MD	71.4 ± 28.3	548 ± 272	7973 ± 3291	821 ± 345	6275 ± 2578	377 ± 201	98.8 ± 90.4	27.1 ± 14.3	24.6 ± 12.6
MD-1	54.5 ± 12.2	246 ± 96.4	3802 ± 1055	434 ± 119	3356 ± 833	80.2 ± 92	14.0 ± 31.1	18.4 ± 8.44	11.3 ± 6.03
MD-2	65.1 ± 16.4	361 ± 143	4630 ± 1129	523 ± 131	3977 ± 938	134 ± 104	25.9 ± 38.7	23.9 ± 9.43	15.9 ± 8.03
MD-3	65.2 ± 16.1	381 ± 158	5343 ± 1742	591 ± 192	4479 ± 1358	197 ± 185	57.7 ± 63.7	23.3 ± 10.7	16.2 ± 8.68
MD-4	59.3 ± 11.9	325 ± 108	4599 ± 1078	528 ± 128	3912± 861	161 ± 173	30.1 ± 50.0	22.3 ± 10.4	14.7 ± 7.08

Table 2 - Results of PCA for MD and each training day

	Principal Component				Principal Component		
	1	2	3		1	2	3
MD				MD-3			
Eigenvalue	6.1	1.1	-	Eigenvalue	4.9	1.1	-
% of Variance	76.0	13.7	-	% of Variance	60.6	13.5	-
Cumulative Variance %	76.0	89.7	-	Cumulative Variance %	60.6	74.25	-
	Rotated Component				Rotated Component		
	1	2	3		1	2	3
% of Variance	54.2	35.5	-	% of Variance	45.9	28.2	-
Rotated Component Loadings				Rotated Component Loadings			
	1	2	3		1	2	3
sRPE	**0.89**	0.30	-	sRPE	**0.79**	0.14	-
Total Distance	**0.94**	0.30	-	Total Distance	**0.89**	0.35	-
PlayerLoad	**0.91**	0.37	-	PlayerLoad	**0.89**	0.32	-
LI.Running	**0.96**	0.24	-	LI.Running	**0.92**	0.21	-
Running	0.58	**0.72**	-	Running	0.29	**0.72**	-
Sprinting		**0.94**	-	Sprinting		**0.89**	-
Accelerations	0.49	**0.77**	-	Accelerations	0.44	0.60	-
Decelerations	0.59	0.69	-	Decelerations	0.58	0.56	-
	Principal Component				Principal Component		
	1	2	3		1	2	3
MD-1				MD-4			
Eigenvalue	4.52	1.18	-	Eigenvalue	4.34	1.49	
% of Variance	56.55	14.75	-	% of Variance	54.22	18.65	
Cumulative Variance %	56.55	71.31	-	Cumulative Variance %	54.22	72.86	
	Rotated Component				Rotated Component		
	1	2	3		1	2	3
% of Variance	50.74	20.57	-	% of Variance	51.35	21.52	
Rotated Component Loadings				Rotated Component Loadings			
	1	2	3		1	2	3
sRPE	0.69		-	sRPE	0.68		-
Total Distance	**0.89**	0.28	-	Total Distance	**0.91**	0.21	-
PlayerLoad	**0.91**	0.16	-	PlayerLoad	**0.91**	0.13	-
LI.Running	**0.91**	0.13	-	LI.Running	**0.93**		-
Running	0.39	**0.76**	-	Running	0.24	**0.86**	-
Sprinting		**0.92**	-	Sprinting		**0.90**	-
Accelerations	0.68	0.15	-	Accelerations	**0.7**	0.29	-
Decelerations	**0.71**	0.3	-	Decelerations	**0.76**	0.13	-
	Principal Component						
	1	2	3				
MD-2							
Eigenvalue	4.15	1.23	1.02				
% of Variance	51.90	12.72	12.72				
Cumulative Variance %	51.90	67.30	80.02				
	Rotated Component						
	1	2	3				
% of Variance	39.60	20.74	19.68				
Rotated Component Loadings							
	1	2	3				
sRPE	0.69	0.15					
Total Distance	**0.92**	0.21	0.25				
PlayerLoad	**0.88**	0.27	0.17				
LI.Running	**0.95**	0.16					
Running	0.25	0.15	**0.81**				
Sprinting			**0.88**				
Accelerations	0.23	**0.86**	0.14				
Decelerations	0.22	**0.85**	0.12				

Percentage of variance explained is shown for both unrotated principal components and rotated components. Loadings that met interpretation criteria (>0.70) are highlighted in bold. Three components were retained for MD-2, whilst two were identified for all other training days, and match-play. The variance explained ranged from 71.31% to 89.7%. Component 1 was generally characterised by measures of volume, with the largest amount of variance being shown on MD.

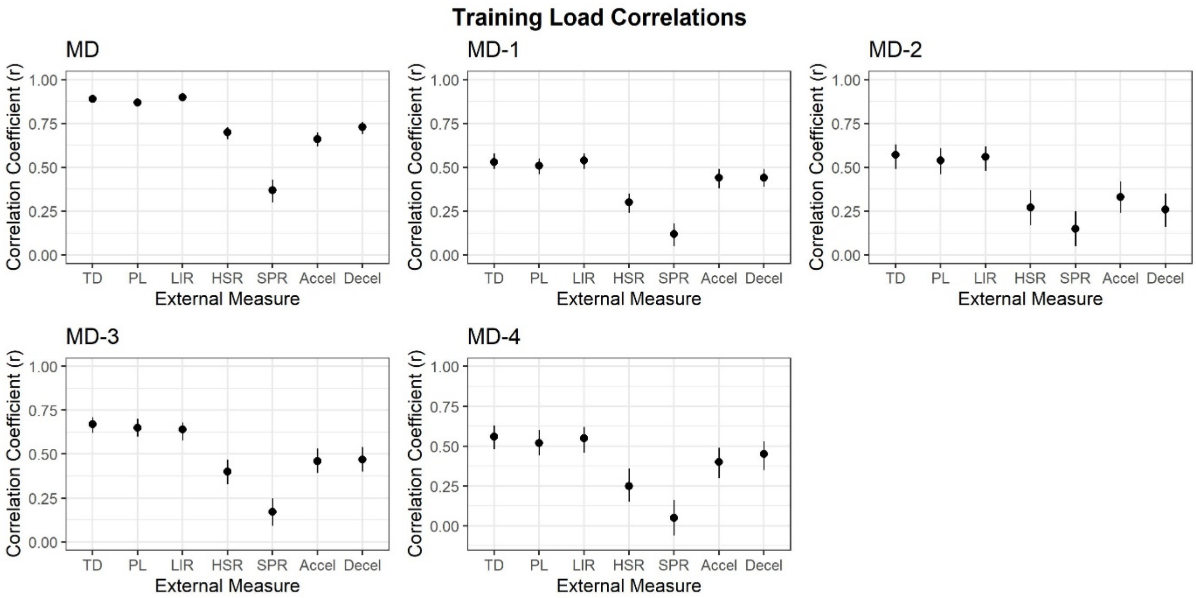

Figure 1 - Pearson's product moment correlations between sRPE and all external load measures (error bars represent 95% CI). TD - Total Distance, PL - PlayerLoad, LIR - Low intensity running, HSR - Running, SPR - Sprinting, Accel - Accelerations, Decel - Decelerations.

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