Achieving a desired training intensity through the prescription of external training load variables in youth sport; more pieces to the puzzle required

Running title: Can external training variables distinguish sRPE?

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Abstract

Identifying the external training load variables which influence subjective internal response will help reduce the mismatch between coach intended and athlete perceived training intensity. Therefore, this study aimed to reduce external training load measures into distinct principal components (PC's), plot internal training response (quantified via session Rating of Perceived Exertion [sRPE]) against the identified PC's and investigate how the prescription of PC's influences subjective internal training response. Twenty-nine school to international level youth athletes wore microtechnology units for field-based training sessions. SRPE was collected post-session and assigned to the microtechnology unit data for the corresponding training session. 198 rugby union, 145 field hockey and 142 soccer observations were analyzed. The external training variables were reduced to two PC's for each sport cumulatively explaining 91%, 96% and 91% of sRPE variance in rugby union, field hockey and soccer respectively. However, when internal response was plotted against the PC's, the lack of separation between low, moderate and high intensity training sessions precluded further analysis as the prescription of the PC's do not appear to distinguish subjective session intensity. A coach may therefore wish to consider the multitude of physiological, psychological and environmental factors which influence sRPE alongside external training load prescription.

Keywords: Periodisation, Training Load, Youth Sport, GPS

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Introduction

Regardless of whether an individual's motivation to participate in sport is to achieve long-term career success as a professional athlete, experience short term enjoyment or undertake compulsory structured activities within school, athletic development programs have the potential to enhance the health, fitness, and performance of all youth athletes (Lloyd et al., 2016, 2015). Frequent exposure to sports training, often through participation in multiple sports or for multiple sides within the same sport (Phibbs et al., 2016) provides enjoyment alongside opportunities to improve physical, technical, tactical and psycho-social attributes (Soligard et al., 2016). Despite this, an accumulation of training and subsequent fatigue without adequate recovery may predispose the athlete to a maladaptive training response (e.g., non-functional overreaching, injury) (Matos, Winsley, & Williams, 2011). Previous research showed that 29% of youth athletes (ranging from local to international level) suffered from non-functional overreaching at some point in their careers (Matos et al., 2011). A prolonged period of non-functional overreaching can lead to a withdrawal from sport negating the benefits of sporting participation and contrasting the aims of youth athletic development (Difiori et al., 2014).

To optimise youth development and guard against negative training responses, coaches must plan for periods of intense training integrated with periods of recovery through the manipulation of training volume, intensity and frequency. These are collectively known as training load (Shaun J Mclaren, Hurst, Spears, & Weston, 2017). Training load can be separated into external and/or internal load (Impellizzeri, Marcora, & Coutts, 2019). External load is the physical work prescribed in the training plan whilst the internal load is reflective of the psychophysiological response of the individual to the external load (Impellizzeri et al., 2019). Despite the association between external load prescription and internal response, individuals may respond differently to the same external training load due to multiple factors (e.g. training, nutritional and health status) (Impellizzeri et al., 2019). Therefore, coaches should monitor internal response on an individual basis to ensure the aims of the training program are being met and the athlete is adapting appropriately to the prescribed external training load (Lloyd et al., 2016). A popular method of quantifying internal training load is via session-rating of perceived exertion load (sRPE load) (Phibbs et al., 2017; Scantlebury, Till, Atkinson, Sawczuk, & Jones, 2017). Previously shown to be a valid measure of internal load compared to objective heart rate measures (Alexiou & Coutts, 2008; Impellizeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Scantlebury et al., 2017) and a valid measure of training adaption (Campos-Vazquez, Toscano-Bendala, Mora-Ferrera, & Suarez-Arrones, 2017). Therefore, sRPE load is an appropriate and important measure of training response. Additionally, utilising sRPE load to quantify internal load is a viable option, particularly in sports programs with low resource, due to the limited costs in comparison to other measures of internal load (e.g., heart rate). To establish the sRPE load of a training session, individuals are asked how difficult they found the activity and provide a rating of intensity via a session-rating of perceived exertion (sRPE; measured by a modified Borg category ratio-10 [CR-10] scale). Additionally, individuals are asked how long the activity lasted and provide a session duration to the nearest minute. The two values are then multiplied together to provide a measure of internal load (sRPE load) in arbitrary units (Foster, Brice, & Foster, 2001).

Whilst the importance of achieving congruence between intended training load and athlete perceived load is clear, previous research has displayed a mismatch between coach intended and athlete perceived training sRPE, with coaches underestimating for intended easier sessions (coach sRPE: 1.9 ± 0.3 *vs.* athlete sRPE: 3.8 ± 2.2) and overestimating (coach sRPE; 5.2 ± 0.6 *vs.* athlete sRPE: 4.5 ± 2.1) for intended harder sessions (Brink, Kersten, & Frencken, 2016; Scantlebury, Till, Sawczuk, Weakley, & Jones, 2018). Microtechnology units are becoming increasingly common place within sport, capturing the intensity, duration, frequency and composition of the activities completed by athletes (e.g., walking, accelerating, sprinting, collisions) (Malone, Lovell, Varley, & Coutts, 2017). Previous literature has sought to identify the association between external training load variables and session intensity via sRPE (Bartlett, O'connor, Pitchford, Torres-Ronda, & Robertson, 2017; David Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013; Gaudino et al., 2015; Lovell, Sirotic, Impellizzeri, & Coutts, 2013; Scott, Black, Quinn, & Coutts, 2013). Establishing the relationship between external load variables and internal response may reduce the disharmony between coach intended and athlete reported sRPE, supporting coaches in the manipulation of external training variables to obtain a desired training intensity (Shaun J Mclaren et al., 2017).

Research in senior male soccer (David Casamichana et al., 2013) and professional rugby league (Lovell et al., 2013) found low to moderate correlations between sRPE and average speed (i.e, $m \cdot min^{-1}$), high speed running (HSR) and PlayerLoad (PL) per minute. Larger correlations were found between sRPE and total distance (TD) (ρ = 0.77 [95% CI = 0.75 – 0.79]) and HSR (ρ = 0.69 [95% CI = 0.67 – 0.71] in a sample of senior male Australian rules football players, with total distance covered being the predominant predictor of internal response (Bartlett et al., 2017). Whilst previous research provides important, albeit inconclusive, information regarding the association between external training load measures and sRPE in senior sport, to the authors knowledge, there is a sparsity of information available in youth sport. As age and playing experience influences sRPE (Barroso, Cardoso, Carmo, & Tricoli, 2014; Gallo, Cormack, Gabbett, Williams, & Lorenzen, 2014), it is possible that the external training load measures which influence sRPE in senior sport may differ from those which influence subjective internal response in youth sport. As such, coaches may not be aware of the external load measures that they need to manipulate in order to achieve the desired subjective internal load response.

The use of microtechnology units allows multiple, and often correlated, external training load measures (e.g., velocity and duration derived metrics) to be collected, leading to multicollinearity and redundancy in the dataset (Weaving et al., 2018). Subsequently, it is difficult to isolate the influence of independent variables (external training load measure) on the dependent variables (internal response) (Weaving et al., 2018). Principal Component

Analysis (PCA) is an orthogonal data reduction technique, which removes multicollinearity from the data set (Weaving et al., 2018) by grouping highly correlated variables into distinct principal components (Williams, Trewartha, Cross, Kemp, & Stokes, 2017). The identified principal components may be viewed in a reduced 2-dimensional (eigen) space clustering internal response in relation to the prescription of the principal components (comprised of external training load measures). From there, the data may be visually inspected to identify differences in internal response (e.g. do perceived higher intensity sessions separate from perceived lower intensity sessions?). Should a visual difference exist, further statistical analysis may be utilised to determine the relationship between the principal components and internal response, providing practitioners with valuable information regarding the manipulation of external training load measures and subsequent subjective internal response.

Therefore, the first aim of this study was to investigate, via PCA, the multivariate relationships between different external training intensity measures collected by microtechnology units. Secondly, the aim was to visually inspect whether the external intensity principal components could discriminate between perceived low, moderate and high sRPE responses between different training sessions in youth sports.

Method

Participants

Twenty-nine adolescent athletes including 8 male soccer players (age 16.7 ± 0.8 years, height 174.4 ± 3.9 cm, body mass 70.4 ± 8.7 kg), 11 male rugby players (age 17.2 ± 0.4 years, height 175.3 ± 13.8 cm, body mass 77.8 ± 21.1 kg) and 10 female field hockey players (age 16.7 ± 0.8 years, height 164.7 ± 6.4 cm, body mass 60.1 ± 6.3 kg) were recruited from an independent school in the United Kingdom. The athletes sport experience, defined as the number of years they have participated in organised sport, was 8.4 ± 3.4 years and current playing standards ranged from non-representative (club/school level) (n=17) to representative (county, academy, international) (n=12) standard. Coaches, players and parents provided informed written consent prior to participation. Ethics approval was granted by the university's ethics committee.

Design of study

The study used a prospective observational, longitudinal research design, whereby data were collected over a 14-week in-season training period. Coaches were instructed to carry out their normal training sessions with no interference from the researcher. Each participant was assigned a micro-technology device (Optimeye S5, Catapult, Melbourne, Australia) that contained a GPS system sampling at 10 Hz and a tri-axial accelerometer, gyroscope and magnetometer sampling at 100 Hz to avoid inter-unit error. The external training variables chosen for analysis were; total distance (meters), lower intensity running (LIR) (meters), higher intensity running (meters), PlayerLoad (AU) and $PlayerLoad_{slow}$ (PL_{slow}) (AU). Only data obtained from field-based training sessions were analysed. Training weeks predominantly contained two field-based training sessions per week structured around a mid-week fixture. A total of 486 observations were collected over the research period, 198 rugby observations with (mean ± SD) 17 ± 8 collected per participant, 145 field hockey observations with 15 ± 6 per participant and 143 soccer sessions with 18 ± 6 per participant. Perceptions of session intensity (sRPE) were collected approximately 30 minutes after each session with participants asked, in isolation, to provide a measure of intensity via a modified Borg category ratio-10 (CR-10) scale to the lead researcher. Following training, coaches were provided with athlete sRPE information and an external training load summary of the training session to facilitate future training load prescription.

Procedures

Participants wore their assigned microtechnology unit for all field-based training sessions during the 14-week data collection period. The microtechnology unit contained a 10 Hz GPS, which has been previously shown to be more reliable than 5 and 15 Hz GPS systems (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014; Rampinini et al., 2014) with a typical error (expressed as coefficient of variation; CV) of 1.9 and 4.7 for TD and HSR (>4.7 $m \cdot s^{-1}$) respectively (Rampinini et al., 2014). The 100 Hz accelerometer housed in the microtechnology unit has also been shown to have an acceptable CV for within (0.9–1.1%) and between (1.0–1.1%) unit reliability (Boyd, Ball, & Aughey, 2011).

Prior to data collection, participants completed a 40m linear sprint whilst wearing their assigned microtechnology unit to obtain a maximum velocity which was subsequently used to calculate individual HIR thresholds. The threshold for HIR was set at 61% of the individuals peak running velocity, determined by the individuals fastest 10m split of the 40m sprint (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010). Lower intensity running was considered to be <61% of the individual's peak velocity. The use of individualised speed thresholds opposed to absolute thresholds has been advocated to provide a more accurate gauge of HIR demands (Reardon, Tobin, & Delahunt, 2015). The units were placed within a pocket in the vest provided by the manufacturer, worn between the scapulae. All microtechnology units were activated outside, 15 minutes before the beginning of each training session to allow acquisition of satellite signals. Following training, participants returned their microtechnology units to the lead researcher and the data were downloaded and analysed using the software provided by the manufacturer (Catapult sprint 5.17, Catapult Innovations, Melbourne, Australia). Each microtechnology unit file was monitored and trimmed individually so only data from the actual training session were analysed. The 'warm up' section of each training session was excluded from analysis, however rest periods during the session were included. Additionally, data were only analysed for participants who completed full training sessions - data from participants who did not complete the full training session were discarded from the analysis.

Following each training session participants provided a sRPE measure to the lead researcher. The sRPE selection was made non-verbally by pointing to the desired text descriptor on a modified Borg category-ratio 10 (CR-10) scale, in isolation from other participants to avoid external influence on selection. Measures of sRPE were taken approximately 30 min following each training session to avoid any influence of activities completed towards the end of each training session on sRPE (Foster, Florhaug, et al., 2001). All participants were familiar with sRPE load collection as the method had been integrated into practice throughout the previous season to quantify subjective internal load. To increase the robustness of analysis, the sRPE number was then grouped as low (sRPE: <4 AU), moderate (sRPE: >4 and <7) or high (sRPE >7) (Figueiredo, Figueiredo, Moreira, Gonçalves, & Dourado, 2019; Lovell et al., 2013) intensity and assigned to the corresponding microtechnology unit file ready for subsequent analysis.

Data analysis

A correlation coefficient matrix was constructed for each sport (Table 1) to assess the strength of the relationships between each of the external training load measures and determine the necessity of PCA. The magnitude of the correlations were assessed as follows*;* <0.1 trivial, 0.1 to 0.3 small, 0.3 to 0.5 moderate, 0.5 to 0.7 large, 0.7 to 0.9 very large, and 0.9 to 1.0 almost perfect (Hopkins, Marshall, Batterham, & Hanin, 2009).

Three separate PCAs of all external training load variables (i.e. TD, LIR, HIR, PL, and PL_{Slow}) were undertaken for each sport, according to established methods (Weaving et al., 2018). The PCA algorithm constructs a new set of linear components (i.e. principal components [PC]), equal to the number of inputted variables, whereby the first component explains the most amount of variance (i.e. information) and the last component explains the least. This reduces the dimensionality of the dataset, thus reducing its complexity and allows for visualisation of the individual sRPE responses in a 2-dimensional space (i.e. scatter plot).

The data were initially mean centred and standardised to unit variance, giving an $M \times N$ matrix (X). The covariance matrix of X was then computed by $X^T X$. The eigenvalues and eigenvectors were then determined from the covariance matrix via eigendecomposition. Finally, the original data were then projected onto the eigenspace of the covariance matrix, giving a matrix of PCs, sometimes referred to as PC scores. The first and second PCs were extracted, since they explain the most amount of variance in the dataset and two PC's were required to produce subsequent scatter plots. Additionally, the first and second PC's had eigenvalues >1, with an eigenvalue >1 a typical threshold utilised to determine which PC's to extract (Weaving et al., 2018; Williams et al., 2017).

Using these PCs, a scatter plot was then created for each sport. After which the individual observations were colour coded according to the sRPE response given by the player after the session (i.e. low, moderate, or high intensity); this allowed for visualisation of any clusters formed. To assist in visualising the clusters, convex hulls were plotted around each sRPE response descriptor for each sport. All data analyses were completed in R Studio (Version 1.1.383), and the PCA was completed using the *prcomp* function from the *stats* package.

Results

Table 2 displays the external and internal training load measures for each sport. Figure 1 displays the scree plots for each PCA, including the eigenvalue and associated fractional variance attributed to each PC. For soccer, 68% and 23% of sRPE variance was explained by PC 1 and PC 2 respectively, cumulatively explaining 91% of sRPE variance. For hockey, PC 1 explained 75% and PC 2 21%, cumulatively explaining 96% of sRPE variance. For rugby union, 73% and 18% of variance was explained by PC 1 and 2 respectively, cumulatively explaining 91% of sRPE variance.

Table 3 displays the component loading for both PC's for each of the sports. Component loadings display the contribution of each of the original external training variables to each of the PCs created for each sport. Figure 2 plots PC1 against PC2, with each observation colour coded according to the perceived sRPE response (low, moderate, high intensity) for each sport, facilitating the visual interpretation of how subjective internal responses cluster together. Using soccer as an example, if an internal response is situated at the top right of the plot (high PC1 & PC2) it would suggest high TD, LIR, HIR, PL & PL_{slow}. Alternatively, if the internal response is situated at the bottom right of the plot, it would suggest high TD, LIR and PL but low PL_{slow} and HIR as the internal response would have a positive score for PC1 and a negative score for PC2.

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Discussion

This study aimed to reduce external training load measures (TD, LIR, HIR, PL & PL_{slow}) into distinct PC's for each sport. The subjective internal response from 198 rugby, 145 field hockey and 143 soccer training sessions were then plotted against the identified PC's to visually inspect how internal responses separated/clustered together. Two PC's were identified for each sport which cumulatively explained 86%, 93% and 86% of variance for soccer, field hockey and rugby union respectively. For PC1, total distance, LIR, and PL had greater component loadings for soccer, field hockey and rugby union. For PC2, HIR and PL_{slow} had greater component loadings and therefore captured unique additional variance. Such findings substantiate previous research in senior professional rugby union skills training, which also reported TD and PL to load together on PC1 and capture the greatest proportion of variance with HIR explaining additional unique variance on PC2 (Weaving et al., 2018).

Component loadings for TD, PL and LIR remain consistent for PC1 (displayed in table 5) for all sports. However, slight differences were found for PC2 component loadings across sports with the HIR 'loading' greater for soccer (0.89) and field hockey (0.92) compared to rugby union (0.64). Conversely, the component loading for PL_{slow} was greater for rugby union (0.79) compared to field hockey (0.38) and soccer (0.43). This is likely due to the greater collision/wrestling/grappling activity in rugby union, increasing PL_{slow} and the reduced spatial constraints in hockey and football (*vs.* rugby union), allowing more opportunities to move at speeds greater than the high-speed threshold used in the current study (>61% peak velocity). The homogeneity of component loadings for TD, PL and LIR on PC1 as well as the additional variance captured by HIR & PL_{slow} on PC2 provides practitioners with valuable information regarding which external load variables require monitoring during field-based training. For example, component loadings on PC1 for soccer were the same (0.52) for TD, PL and LIR, likely due to the large association between TD & PL (D Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013) and the vast majority of TD comprised of LIR. Therefore, soccer practitioners may monitor either TD or PL or LIR, alongside HIR & PL_{slow} (which captured unique information on PC2), rather than monitoring TD and PL and LIR. Similar to previous research (Weaving et al., 2018; Weaving, Marshall, Earle, Nevill, & Abt, 2014; Williams et al., 2017), the findings of this study demonstrate the usefulness of PCA to understand which measures are capturing similar or unique information depending how closely they 'load' onto each PC. Such findings refine the monitoring process as analysing multiple external load variables can be time consuming and unnecessary as each metric (TD, PL & LIR) provides the same information regarding the training session.

Despite this, when the PC scores of the 1st and 2nd PCs were plotted (Figure 2) the homogeneity of the internal responses precluded further linear or non-linear (e.g. machine learning) analysis, as it was clear that the external load measures could not discriminate between subjective perceptions of low, moderate or high intensity training. Therefore, whilst further research is required to determine if external training load measures can discriminate objective internal response (e.g. heart rate), to accurately design a training session aimed at eliciting a desired subjective internal response in rugby union, soccer and field hockey, coaches require more information than can be derived through the TD, LIR, HIR, PL and PL_{slow} of a training session.

Previous research has identified an inconsistent relationship between external training load measures and sRPE. Correlations between average speed, HSR·min^{-1}, PlayerLoad·min^{-1} and sRPE range from low to moderate in semi-professional male soccer and professional male rugby league (David Casamichana et al., 2013; Lovell et al., 2013) whilst small correlations between HSR·min^{-1}, impacts/m and accelerations/m have also been found in professional male soccer (Gaudino et al., 2015). Contrastingly, research within senior male Australian rules football has found large relationships between TD, HSR and sRPE (Bartlett et al., 2017). Further analysis found TD to be the most important variable in determining sRPE for 87% of athletes whereas average speed, HSR and HSR % were the most important variables for the remainder of the squad. Despite TD being the predominant predictor of sRPE, the variability within the squad highlights the influence of individual characteristics on sRPE, providing an explanation for the small to moderate correlations found in previous research and the lack of differentiation in perceived low, moderate and high intensity training sessions in this study.

The influence of individual characteristics on sRPE has been identified in Australian rules football with playing experience, time trial performance and playing position all having an effect on sRPE when external training load was controlled for (Gallo et al., 2014). Furthermore, personality factors such as extraversion, neuroticism, and anxiety have been proposed to affect sRPE alongside conditions such as coach instruction, athlete nutrition and mobilisation of attentional resources (Haddad, Padulo, & Chamari, 2014). The multitude of psychological, physiological and environmental factors influencing sRPE may be responsible for the varied internal responses to training irrespective of the external load (Impellizzeri et al., 2019) providing an explanation for the difficulty in distinguishing low, moderate and high intensity training sessions with external training load measures alone.

It is possible that the investigated external training load variables failed to provide a holistic quantification of the demands of training due to limitations of the microtechnology unit. Accelerations and decelerations are frequent within team sport training and elicit a high metabolic and neuromuscular cost (Cummins, Orr, & Connor, 2013). However, the validity of accelerations, measured via 10 Hz microtechnology units are compromised when over 4 $m \cdot s^{-2}$, and were consequently not considered for analysis (Akenhead, French, Thompson, & Hayes, 2014). Despite the difficulty in accurately measuring accelerations/decelerations it cannot be overlooked that these elements of a training session will likely affect sRPE and might provide important information relating to the external load measures that can distinguish perceived session intensity.

As the prescription of the two PC's identified for each sport do not appear to distinguish perceived session intensity, the complexity of a coach achieving a desired internal response from their athletes is highlighted. Whilst external training load variables may have large associations with sRPE (McLaren et al., 2018), individual response to external load is influenced by multiple factors unique to the individual with athletes responding differently to the same prescribed external load (Impellizzeri et al., 2019). Therefore, to achieve a 'hard' training session, a coach cannot simply prescribe a session requiring athletes to run further and/or faster and must consider factors such as athlete pre-training status, the technical and cognitive demands of the training session and environmental conditions (Haddad et al., 2014; S J Mclaren, Smith, Spears, & Weston, 2017). Whilst this appears to be a challenging task due to the multiple factors influencing sRPE, the importance of understanding factors influencing sRPE is clear. Moderate to high training loads are required within team sports to facilitate adaption and ensure players are capable of meeting the demands of competition (Gabbett, 2016; Hulin et al., 2014). However, a prolonged period of intense training without the incorporation of recovery or 'easier' sessions can lead to an accumulation of fatigue and subsequent performance impairment, injury, illness and sporting burnout (Difiori et al., 2014; Matos et al., 2011). Further research is required to enhance the understanding of the psychological, physiological and environmental factors that influence sRPE in youth team sports and how these factors combine with the prescription of external training load variables to distinguish session intensity. Such findings will inform training prescription, allowing practitioners to manipulate training variables to achieve a desired subjective internal response from athletes. However, at present, the external training load variables comprising the identified PC's in this study do not provide sufficient information to clearly distinguish subjective perceptions of low, moderate and high intensity training sessions in youth team sport athletes.

Conclusion

Following principal component analysis, two PC's were identified for each sport. For PC1, TD, LIR and PL had greater component loadings whilst HSR and PL_{slow} had greater component loadings on PC2 subsequently explaining additional variance for all sports. Despite this, when separated into perceived low, moderate and high intensity training sessions and plotted against the identified PC's, internal responses cluster together suggesting the prescription of the PC's do not distinguish subjective low, moderate and high intensity training sessions.

Practical applications

Total distance, PlayerLoad and lower intensity running 'loaded' on PC1 with similar component 'loadings' for all sports. Higher intensity running and $PlayerLoad_{slow}$ explained additional information on PC2 for all sports. Therefore, soccer, field hockey and rugby union practitioners may refine their monitoring process by analysing TD or PL or LIR as well as HIR and PL_{slow}. Despite this, subjective perceptions of training intensity (low, moderate, high) cluster together when plotted against the identified principal components (comprised of external training load measures). Therefore, rugby union, field hockey and soccer practitioners cannot simply orchestrate subjective session intensity by manipulating the external load (LIR, HIR, PL & PL_{slow}) of a training session. Whilst further research is required to understand how individual and environmental factors moderate the sRPE response to the external load prescribed, at present, coaches may take sRPE on an individual basis during the training session, subsequently altering the athlete's session to align with the coaches periodised plan.

Disclosure of interest

The authors report no conflict of interest.

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Table 1. Correlation matrix for the external training load measures collected during rugby union, field hockey and soccer training sessions

Rugby Union					
	TD	***LIR***	***HIR***	***PL***	***PL_{slow}***
TD	1				
LIR	0.95	1.00			
HIR	0.99	0.94	1.00		
PL	0.52	0.46	0.43	1.00	
PL_{slow}	0.65	0.74	0.67	0.12	1.00
Field Hockey					
	TD	***LIR***	***HIR***	***PL***	***PL_{slow}***

TD	1				
LIR	0.99	1.00			
HIR	0.25	0.08	1.00		
PL	0.95	0.93	0.32	1.00	
PL_{slow}	0.79	0.85	-0.19	0.77	1.00

Soccer

	TD	***LIR***	***HIR***	***PL***	***PL_{slow}***
TD	1				
LIR	0.99	1.00			
HIR	0.31	0.20	1.00		
PL	0.85	0.86	0.16	1.00	
PL_{slow}	0.54	0.58	-0.16	0.77	1.00

Table 2; The mean ± SD of the external and internal training variables analysed for each sport

	TD (m)	**LIR (m)**	**HIR (m)**	**PL (AU)**	**PL_{Slow} (AU)**	**sRPE (AU)**	**sRPE Load (AU)**
Rugby Union	2460 ± 865	2346 ± 816	112 ± 102	233 ± 76	114 ± 34	4 ± 1	135 ± 80
Field Hockey	2176 ± 879	2068 ± 852	106 ± 145	192 ± 73	118 ± 41	3 ± 2	172 ± 131
Soccer	3253 ± 861	3141 ± 834	109 ± 99	334 ± 88	165 ± 42	4 ± 1	187 ± 94

Table 3; The component loadings for PC 1 and PC 2 for each sport

External training variable	***Soccer***		***Field Hockey***		***Rugby Union***	
	PC1	PC2	PC1	PC2	PC1	PC2
TD	0.52	-0.16	0.51	-0.04	0.51	-0.04
LIR	0.52	-0.06	0.51	-0.08	0.49	-0.02
HIR	-0.11	0.89	-0.17	0.92	-0.29	0.64
PL	0.52	-0.06	0.50	-0.06	0.51	-0.08
PL_{slow}	0.42	0.43	0.45	0.38	0.39	0.79

Figure 1; The scree plots for each PCA and the associated fractional variance attributed to each PC

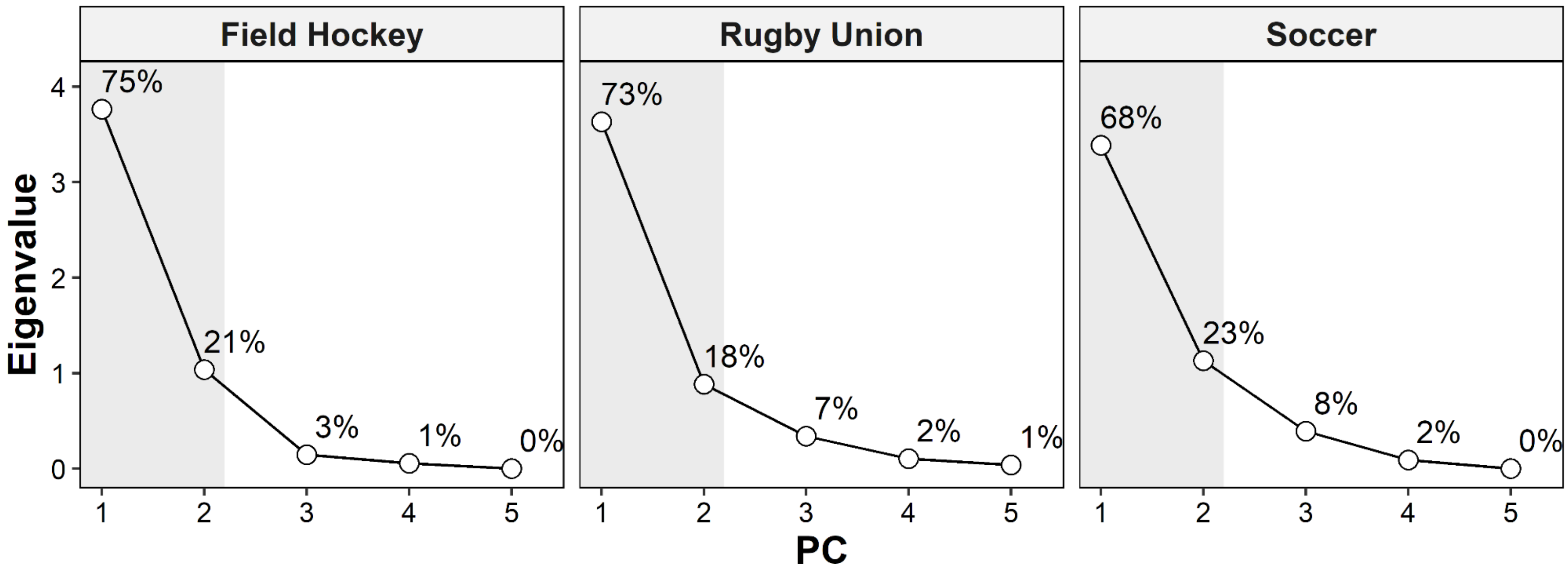
Field Hockey
Rugby Union
Soccer
Eigenvalue
PC
75%
21%
3%
1%
0%
73%
18%
7%
2%
1%
68%
23%
8%
2%
0%

Figure 2; The PC scores for PC1 and PC2, colour coded by perceived session intensity for each sport, including convex hulls around each descriptor.