A combination of internal and external training load measures explains the greatest proportion of variance in certain training modes in professional rugby league

Journal:	*International Journal of Sports Physiology and Performance*
Manuscript ID:	IJSPP_2013_0444.R3
Manuscript Type:	Original Investigation
Keywords:	athletic training, sport physiology

A combination of internal and external training load measures explains the greatest proportion of variance in certain training modes in professional rugby league

Submission Type: Original Investigation

Authors: Dan Weaving[1], Phil Marshall[1], Keith Earle[1], Alan Nevill[2], Grant Abt[1]

[1]Department of Sport, Health and Exercise Science, The University of Hull, Kingston upon Hull, UK.
[2]School of Sport, Performing Arts and Leisure, University of Wolverhampton, Walsall, UK.

Corresponding Author:
Dr Grant Abt
Department of Sport, Health and Exercise Science,
Don Building
The University of Hull, Kingston upon Hull, UK
T: +44 (0)1482 463397
Email: g.abt@hull.ac.uk

Running Head: Training load in rugby league

Abstract Word Count: 216
Text-Only Word Count: 3398
Figures/Tables: 1 x Figure; 3 x Tables

Abstract

Purpose: This study investigated the effect of training mode on the relationships between measures of training load in professional rugby league players. **Methods:** Five measures of training load (Internal - iTRIMP, session-RPE; External - Bodyload, high-speed distance, total impacts) were collected from 17 male rugby league players over the course of two 12-week pre-season periods. Training was categorised by mode (small-sided games, conditioning, skills, speed, strongman and wrestle) and subsequently subjected to a principal component analysis. Extraction criteria were set at an eigenvalue of greater than one. Modes that extracted more than one principal component were subjected to a varimax rotation. **Results:** Small-sided games and conditioning extracted one principal component, explaining 68% and 52% of the variance respectively. Skills, wrestle, strongman and speed extracted two principal components explaining 68%, 71%, 72% and 67% of the variance respectively. **Conclusions:** In certain training modes the inclusion of both internal and external training load measures explained a greater proportion of the variance than any one individual measure. This would suggest that in those training modes where two principal components were identified, the use of only a single internal or external training load measure could potentially lead to an underestimation of the training dose. Consequently, a combination of internal and external load measures is required during certain training modes.

Keywords: session-RPE, iTRIMP, Bodyload, high-speed running, impacts.

Introduction

Rugby league players engage in a diverse range of training modes in order to induce adaptations needed to succeed in competition.[1] However, given the inter-individual variability in responses to any prescribed training session, it is imperative that sports scientists are able to utilise valid and reliable methods to monitor an individual's load during all training modes in order to optimise the training process.[1] At present, there are numerous methods used to monitor both the internal and external load, including heart rate (HR) based TRIMP methods, session-RPE (sRPE) (internal training load) and microtechnologies such as GPS and accelerometers (external training load).[2-4] However, due to the lack of a 'gold-standard' criterion, previous research has investigated load validity against other available measures of load[2,3] or with changes in fitness measures.[4,5] Very large associations have been reported between sRPE and Banisters TRIMP (r = 0.73) and Edward's TRIMP (r = 0.77) during in-season training of professional soccer players.[3] Similar very large associations have also been found between sRPE and measures of external load including total distance (r = 0.80) and PlayerLoad™ (r = 0.84).[3] However, the validity of the criterion measures of internal load used to validate sRPE in previous studies has been questioned as they may not reflect the individualised physiological response to high-intensity intermittent activity.[4,5] As a result, the individualised TRIMP (iTRIMP) was developed to alleviate the limitations of previous TRIMP methods, with the iTRIMP displaying dose-response validity and sensitivity as a measure of the internal load in both youth and professional soccer players.[4,5]

The difficulty in monitoring load is further compounded due to the wide range of training modes that rugby league players undertake, which on occasions includes collision and contact episodes.[2] Differences in PlayerLoad™ between training modes (skills, small- sided games, tactical and match practice) have previously been described[6], which suggests that the training modality may influence the external loads that players are subjected to. Despite this, there is very limited information available within the literature regarding how the training mode might influence the validity of the various load methods in rugby league. This is important to determine, as it may be possible that the load is underestimated during particular training modes. The relationship between sRPE and external load measures during various training modes in professional rugby league players has previously been described.[2] Whilst not the primary aim of that study, the training mode altered the strength of the relationships reported. For example, the association between sRPE and Bodyload™ ranged from moderate (r = 0.45) during wrestling to large (r = 0.64) during skills conditioning.[2] Variation in the relationships between sRPE and other measures of load was also present amongst different training modes.[2] This suggests that the training mode influences the validity of sRPE to quantify the load. This is logical as training modes have differing external load structures in an attempt to produce different physiological adaptations. For example, speed sessions have extensive recovery periods due to the short-duration, maximal intensity bouts needed to stimulate adaptations that contribute to improved sprinting speed (e.g. muscle contraction velocity).[7] This is in contrast to small-sided games, where the sessions are of a longer duration and of an intermittent nature in order to replicate the movement patterns of competition.[8] The extensive rest periods found in modes such as skills and speed training have previously been suggested to reduce the perception of effort.[3] Dependent on the training mode, it may be possible that training load measures could be used interchangeably. Conversely, in certain modalities a combination of load measures may be more sensitive to describing the training stress elicited. However, the influence of training mode on other measures of training load has yet to be described.

Therefore, the aim of the current study was to examine the influence of training mode on common measures of training load in professional–rugby league players. In particular, we aimed to determine the structure of the interrelationships amongst measures of training load in order to define common underlying dimensions within the variables via a Principal Component Analysis (PCA). PCA is a mathematical technique used to reduce the dimensionality of any given data set which consists of a number of highly correlated variables, whilst still keeping as much of the variation in the data set as possible.[9,10] We hypothesised that the different external load structures of the various training modes will influence the strength of the variance explained by individual training load measures.

Methods

Participants

Seventeen professional rugby league players from the same European Super League club participated in this study. The participants had the following characteristics; age: 25 ± 3 y; height: 186.0 ± 7.7 cm; mass: 96.0 ± 9.3 kg; 1st Grade playing experience (either Super League or NRL experience): 106 ± 93 matches. The study was granted ethics approval by the Department of Sport, Health and Exercise Science Human Research Ethics Committee in accordance with the Declaration of Helsinki. Written informed consent was obtained from each player prior to the start of the study.

Design

The study used a longitudinal observational research design in which training load data were collected during two 12-week pre-season preparatory periods during the 2011-2012 and 2012-2013 European Super League seasons.

Methodology

Training load measures were assessed via microtechnology (HR, GPS and in-built accelerometer) and the session rating of perceived exertion (sRPE) during each training session. Prior to the start of the study, all players were familiarised with the above methods. The training programme was prescribed by the Super League club coaching staff during the entire study. During the study period, players typically completed 4-5 training sessions per week. Weekly sessions usually included two skills sessions, two conditioning sessions and one skills-conditioning session. Additionally, wrestle, speed and strongman training were included in pre-existing sessions on two occasions per week.

All sessions could be identified as one of the following training modes:

1. small-sided games - small-sided, high-intensity ‘off-side’ and ‘on-side’ conditioning games which aimed to concurrently improve rugby league specific fitness and also the execution of skills under fatigue;
2. conditioning - focus on high-intensity running and hill running which aimed to improve players’ aerobic fitness;
3. skills - focus on enhancing individual rugby league skills and team technical-tactical strategies;
4. speed - maximal intensity running drills which aimed to improve acceleration, speed, agility and sprinting technique;
5. strongman - resistance training, which included compound movements of lifting and pulling unconventional objects that aimed to develop muscular hypertrophy and add an

extra sense of competition and variety into the pre-season preparatory period. Strongman sessions included tyre pushes, flips, and Prowler® pushes. The Prowler® is a training sled that can be dragged or pushed with the option of adding resistance;

6. wrestle - small area, high-intensity contact sessions aimed at improving both tackling and wrestling techniques.

sRPE was calculated for each player during the study period using the method of Foster et al.[11] Exercise intensity for sRPE was determined using Borg's CR-10 scale[12] which was collected ~30 mins following the completion of each training session. sRPE was then multiplied by the training session duration to calculate the sRPE training load in arbitrary units (AU). All players who participated in the study had been familiarised with the RPE scale including the interpretation of exertion in relation to the verbal anchors placed within the scale. Each player completed a staged incremental treadmill test to determine an individual lactate-HR relationship. This relationship was used as part of the calculation for each individual's iTRIMP weighting, as implemented in previous studies.[4,5] Players avoided any strenuous exercise in the 24 hours preceding the incremental treadmill test. Resting HR (HR_{rest}) was recorded (Polar F3, Polar Electro, OY, Finland) from the players in a resting state prior to the first test. The resting state included lying in a supine position in a quiet room. HR_{rest} was taken as the lowest 5 s value during the 5-minute monitoring period. Players then completed the staged incremental test on a motorised treadmill (Woodway ELG55, Woodway, Weil an Rhein, Germany) consisting of five, 4-minute sub-maximal stages commencing at an initial running speed of 7 $km \cdot h^{-1}$ with 1-minute recovery between stages. A finger capillary blood lactate sample was collected during the 1-minute recovery period and immediately analysed in duplicate (YSI 2300, YSI inc, Yellow Springs, OH). Treadmill speed was increased every stage by 2 $km \cdot h^{-1}$ until a maximal speed of 15 $km \cdot h^{-1}$ was reached. Following this, a ramp protocol was used to determine the player's maximal heart rate (HR_{max}). The ramp protocol commenced at an initial speed of 15 $km \cdot h^{-1}$ and increased at increments of 1 $km \cdot h^{-1} \cdot min^{-1}$ until volitional fatigue. Heart rate data were collected throughout the treadmill test every 5 s using Polar HR straps (T14, Polar, Oy, Finland). The highest heart rate recorded at the completion of the ramp protocol was used as the HR_{max}. While the reliability of the iTRIMP treadmill test has not yet been reported,[4,5,13] the blood lactate response to incremental protocols has been reported to show acceptable levels of reliability.[14,15]

The HR_{max} measured during the maximal incremental test was used as the reference value for iTRIMP calculations. The iTRIMP was calculated for each player for each training session for the duration of the study using previously described methods.[13] Briefly, the iTRIMP is described in formula 1:

(1) Duration x ΔHR x ae^{bx}

Where ΔHR equals $HR_{exercise} - HR_{rest}/HR_{max} - HR_{rest}$, a and b are constants for a given player, e equals the base of the Napierian logarithms, and x equals ΔHR.[5] Each player's equation was generated from their own data collected during the incremental treadmill test. Heart rate was collected during each training session (every 5 s) using Polar HR straps (T14, Polar, Oy, Finland) which transmitted continuously to the GPS unit (SPI Pro XII, GPSports, Fyshwick, Canberra). Raw HR data were exported from the GPS manufacturer's software (TeamAMS Version 16.1, GPSports, Canberra, Australia) into dedicated software to determine individual session iTRIMP values (iTRIMP Software, Training Impulse LTD, UK).

External training load measures of distance run at high-speed (high-speed distance), Bodyload™ and total impacts were collected during each session. High-speed distance (>15 km·h^{-1}), Bodyload™ and total impacts were collected concurrently during each training session using 5 Hz GPS devices with 15 Hz interpolation (SPI Pro XII, GPSports, Canberra, Australia). GPS devices have been shown to provide an acceptable level of accuracy and reliability for distance and speed measures during high-intensity, intermittent exercise.[16,17] GPS housed tri-axis accelerometer data displayed in 'g' force and sampling at 100 Hz was used to collect player Bodyload™ and total impacts. Total impacts identification was derived from the summation of impacts in the vertical (z), medio-lateral (y) and anterior-posterior (x) planes. The magnitude of impacts were demarcated according to the following acceleration zones provided by the system manufacturer: 5.0-6.0 g: light impact (zone 1); 6.01-6.5 g: light to moderate impact (zone 2); 6.51-7.0 g: moderate to heavy impact (zone 3); 7.01-8.0 g: heavy impact (zone 4); 8.01-10.0 g: very heavy impact (zone 5); and >10.0 g: severe impact (zone 6). The impact counts within the six demarcated zones were summated to calculate the total number of impacts. Impacts can be detected, particularly in Zone 1, as a result of locomotor impacts due to hard acceleration/decelerations or changes in direction[18]. Therefore, physical contact/collision does not have to be present in order for an impact to be detected[18].

Player Bodyload™ is an arbitrary measure of the total external mechanical stress as a result of accelerations, decelerations, changes of direction and impacts. Player Bodyload™ was calculated using the algorithm included in the software provided by the manufacturers (TeamAMS Version 16.1, GPSports, Canberra, Australia). Player Bodyload™ is calculated from the square root of the sum of the squared instantaneous rate of change in acceleration in the vertical (z), anterior-posterior (x) and medio-lateral vectors (y). The magnitude of the accelerations were classified into six zones (as described above) with a factor (1-6 factor for zones 1-6) applied to each zone. Each player's Bodyload™ score was multiplied by the player's body mass, summed, and then expressed in arbitrary units (AU).

Statistical Analysis

Prior to performing PCA, a visual inspection of the Pearson correlation matrix was conducted in order to determine the factorability of the data for principal component analysis.[18,19] The suitability of the data was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity. KMO (approx. chi-square) values were 0.60 (261.9), 0.62 (305.8), 0.75 (186.8), 0.64 (109.3), 0.58 (113.3) and 0.50 (72.8) for small-sided games, skills, conditioning, speed, strongman and wrestle, respectively. A KMO value of 0.5 or above has been suggested to show the dataset is suitable for PCA.[9,20] Bartlett's Test of Sphericity was significant for each training mode ($p < 0.001$). PCA was used to reduce the data to a set of principal components. Each principal component contains a set of variables that are correlated with each other, whilst the principal components themselves do not correlate. Consequently, each principal component provides distinct information. The five training load measures (iTRIMP, sRPE, Bodyload™, high-speed distance and total impacts) were subjected to a PCA for each training mode using a prior communality estimate of less than one. The stages involved in the calculation for a PCA are (a) deletion of the mean; (b) calculation of the covariance matrix of the data; (c) determination of the eigenvalues and eigenvectors of the covariance matrix and (d) rotation of the original data onto a coordinate system spanned by the eigenvectors of the covariance matrix.[10] Rotation was performed when two principal components were retained, and with the goal of making the component loadings more easily interpretable. A principal axis method was used to extract the components. Components with an eigenvalue of less than 1 were not retained for extraction.[9] This is due to the notion that any component displaying an eigenvalue greater than 1.00 is accounting for a greater proportion of variance than that contributed by any one variable. The Statistical Package for the Social Sciences (SPSS) (Version 20.0 for Windows; SPSS Inc, Chicago, IL) was used to conduct the analysis.

Results

A total of 716 individual training sessions were observed during the study with seventeen players providing 42 ± 13 sessions each. Table 1 displays the number of sessions and mean training loads for each training mode.

******Insert Table 1 here******

Table 2 displays the PCA, including eigenvalues for each principal component in each training mode, and the total variance explained by each principal component for each training mode. There was a single principal component identified for small-sided games and conditioning, whereas two principal components were identified for skills, speed, strongman, and wrestle training modes. Pearson correlations including 95% confidence intervals (CI) between the training load methods for the different training modes are also presented in Table 3.

****** Insert Table 2 here ******
****** Insert Table 3 here ******

Figure 1 shows the rotated component plots for the training modes in which more than one principal component was retained for extraction, including their position within the rotated space.

****** Insert Figure 1 here ******

Discussion

The primary finding of the current study is the identification of more than one principal component for skills, speed, wrestle, and strongman training. For those training modes where two principal components were identified, the component loadings appear to align themselves with either internal load measures or external load measures. For example, during skills training, the highest loadings for the first principal component are for Bodyload™ (0.86) and total impacts (0.87), both external load measures, whereas the highest loadings for the second principal component are for iTRIMP (0.88) and sRPE (0.77), both internal load measures. However, when looking between training modes it can be seen that the first principal component, which explains the greatest amount of variance, alternates between internal and external load measures depending on the type of training. For example, during skills training, the greatest variation is explained by the external load measures Bodyload™ and total impacts. However, during speed training, the greatest amount of variance is explained by the internal measures of sRPE and iTRIMP. These results provide initial evidence that (1) a combination of internal and external training load measures explains a greater proportion of the variance observed than either internal or external measures on their own, and (2) that neither the internal or external measures of load consistently explain the greatest amount of variance across modes of training. As a result, the use of one internal or external training load measure during certain modes of training may underestimate the actual training dose.

Moreover, the training load measure that explains the greatest amount of variance in one training mode may not do so in another training mode.

The presence of two principal components during skills training is potentially an important finding, as skills training can comprise almost half of the training sessions during the competitive season.[2] Previous research[2] has reported smaller correlations between sRPE and other measures of training load during skills training when compared to small-sided games and conditioning. Therefore, the use of one load measure within this training mode could potentially lead to a substantial underestimation of the training dose, which could impact on team performance and injury risk. Whilst the mechanisms behind the present findings are currently speculative, during skills training players spend a large proportion of the time standing or moving at low speeds due to an increase in coaching instruction, tactical focus and waiting to perform the drills interspersed with very short-duration but maximal-intensity locomotor movements. This could potentially lead to a reduction in the perception of effort or delay in HR response.[3] Therefore, the use of at least one external load measure and one internal load measure may be a better approach when monitoring the training load during skills sessions.

The presence of a single principal component and large component loadings for all five training load measures during small-sided games and conditioning suggests that these training load measures are providing similar information. This is supported by the large within-individual correlations between sRPE and all measures of load during small-sided games and conditioning reported in previous research.[2] The external load structures of training modes such as small-sided games involve much higher intensity periods (15.5 PlayerLoad™·min^{-1}) compared to open skills training (10.5 PlayerLoad™·min^{-1}).[6] Therefore, during small-sided games and conditioning there is a prolonged external load component due to the intermittent nature of the activity, which involves a high number of accelerations and decelerations with an increased frequency and a greater magnitude of distance covered at high-intensity.[6] This ultimately leads to a similarly high internal load response.[1] Logically therefore, whether the dose is high or low, the load measures respond in a similar way and account for a similar amount of the variance explained by the single principal component.

Although the current study has found that in some training modes there is a single principal component and therefore training load measures might be used interchangeably, it has previously been suggested that only measures that relate to changes in fitness or performance should be utilised.[5,13] Consequently, further research is required to establish the dose-response relationship of a combination of external and internal load measures for the individual training modes. Such an approach may elucidate how training load measures could be combined in both research and applied work which would allow a greater proportion of the variance to be accounted for when compared to the use of a single training load measure. Finally, although previous research suggests that tri-axial accelerometers in general show acceptable reliability,[22] further research is required to examine the reliability of the accelerometer and derived measures of Bodyload™ and total impacts as used within the current study.

Practical Applications

- Training mode should be considered when deciding on the training load measure used.
- For small-sided games and conditioning training it appears that training load measures could be used interchangeably.

- For skills, speed, wrestle, and strongman training a combination of internal and external training load measures should be considered.

Conclusions

The current study has shown that for skills, speed, wrestle, and strongman training there was more than one principal component identified, suggesting that a combination of both internal and external training load measures are required to maximise the variance explained. During small-sided games and conditioning there was only a single principal component identified which suggests training load measures could be used interchangeably. However, the dose-response relationship with changes in fitness or performance for the combined internal and external training load measures needs to be determined in future studies.

Acknowledgements

Research was conducted with the support of the Hull Kingston Rovers Rugby League Football Club, Hull, UK. We would also like to thank John Perry for additional statistical help.

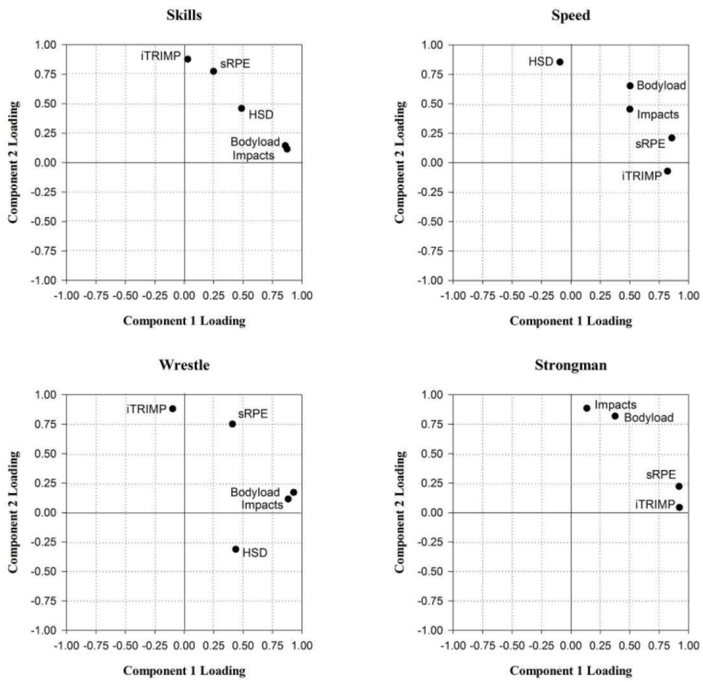
References

1. Impellizzeri F, Rampinini E, Marcora S. Physiological assessment of aerobic training in soccer. *J Sports Sci* 2005;23:583-592
2. Lovell TW, Sirotic AC, Impellizzeri FM, Coutts AJ. Factors affecting perception of effort (session rating of perceived exertion) during rugby league training. *Int J Sports Physiol Perform* 2013;8:62-69
3. Scott BR, Lockie RG, Knight TJ, Clark AC, Janse de Jonge XA. A comparison of methods to quantify the in-season training load of professional soccer players. *Int J Sports Physiol Perform* 2013;8:195-202
4. Manzi V, Bovenzi A, Impellizzeri FM, Carminati I, Castagna, C. Individual training-load and aerobic fitness variables in premiership soccer players during the precompetitive season. *J Strength Cond Res* 2013;27:631-636
5. Akubat I, Patel E, Barrett S, Abt G. Methods of monitoring the training and match load and their relationship to changes in fitness in professional youth soccer players. *J Sports Sci* 2012;30:1473-1480
6. Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *Int J Sports Physiol Perform* 2011; 6:311-321
7. Lockie RG, Murphy AJ, Scott BR, Janse de Jonge XA. Quantifying session ratings of perceived exertion for field-based speed training methods in team sport athletes. *J Strength Cond Res* 2012;26:2721-2728
8. Gabbett TJ, Jenkins DG, Abernethy B. Physiological and skill demands of 'on-side' and 'off-side' games. *J Strength Cond Res* 2010;24:2979-83
9. Kaiser HF. The application of electronic computers to factor analysis. *Educ Psychol Meas* 1960;20:141-151
10. Federolf P, Reid R, Gilgien M, Haugen P, Smith G. The application of principal component analysis to quantify technique in sports. *Scand J Med Sci Sports* 2012; doi: 10.1111/j.1600-0838.2012.01455.x
11. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. A new approach to monitoring exercise training. *J Strength Cond Res* 2001;15:109-115
12. Borg G, Ljunggren G, Ceci R. The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. *Eur J Appl Physiol Occup Physiol* 1985;54:343-349
13. Manzi V, Iellamo F, Impellizzei F, D'Ottavio S, Castagna C. Relation between individualized training impulses and performance in distance runners. *Med Sci Sports Exerc* 2009;41:2090-2096
14. Weltman A, Snead D, Stein P, Seip R, Schurrer R, Rutt R, Weltman JY. Reliability and validity of a continuous incremental treadmill protocol for the determination of lactate threshold, fixed blood lactate concentrations, and VO2max. *Int J Sports Med* 1990;11:26-32
15. Pfitzinger P, Freedson PS. The reliability of lactate measurements during exercise. *Int J Sports Med* 1998;19:349-357
16. Coutts AJ, Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 2010;13:133-135
17. MacLeod H, Morris J, Nevill A, Sunderland C. The validity of a non-differential global positioning system for assessing player movement patterns in field hockey. *J of Sports Sci* 2009;27:121-128

18. McLellan CP, Lovell DI, Gass GC. Biochemical and endocrine responses to impact and collision during elite rugby league match play. *J Strength Cond Res* 2011;25: 1553-1562
19. Tabachnick BG, Fidell LS. *Using Multivariate Statistics.* Boston: Pearson Education Inc; 2007
20. Hair J, Anderson RE, Tatham RL, Black WC. Multivariate Data Analysis. 4th ed. New Jersey: Prentice-Hall Inc; 1995
21. Bartlett MS. A note on the multiplying factors for various chi square approximations. *J R Stat Soc Ser C Appl Stat* 1954; Series B 16:296-298
22. Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *Int J Sports Perform* 2011;6: 311-321

Figure Legend

Figure 1. Rotated component plots of the training modes where more than one principal component was retained for extraction. HSD = high-speed distance; sRPE = session rating of perceived exertion;iTRIMP= individualised TRIMP.



209x148mm (300 x 300 DPI)

Table 1. Means ± SD of training load measures and session durations during each training mode. sRPE: session rating of perceived exertion; SSG: small-sided games; BL: Bodyload; HSD: high-speed distance; iTRIMP: individualised TRIMP.

Training Mode	n	Duration	iTRIMP	sRPE	BL	HSD	Impacts
SSG	88	37 ± 14	85 ± 72	247 ± 190	79 ± 85	479 ± 472	1835 ± 1819
Skills	263	40 ± 24	42 ± 32	182 ± 94	36 ± 33	252 ± 222	1069 ± 965
Conditioning	170	52 ± 22	113 ± 62	441 ± 345	93 ± 73	797 ± 512	3202 ± 2490
Speed	99	28 ± 8	23 ± 18	97 ± 65	28 ± 18	232 ± 159	603 ± 400
Strongman	60	21 ± 8	53 ± 35	229 ± 81	9 ± 13	60 ± 93	391 ± 428
Wrestle	41	19±8	18±10	90±43	11±9	54±77	269±261

Table 2. Results of the PCA, showing the eigenvalue, percentage (%) of variance explained and the cumulative % of variance explained by each Principal Component (PC) for each training mode. Also showing the unrotated (1 PC extracted) or rotated (> 1 PC extracted) training load component loadings for each PC extracted (PC greater than the eigenvalue-one criterion). SSG: small-sided games; Con: conditioning; iTRIMP: individualised TRIMP; sRPE: session rating of perceived exertion; HSD: high-speed distance.

	Component						**Component**				
	1	2	3	4	5		1	2	3	4	5
SSG						**Con**					
Eigenvalue	3.42	0.62	0.52	0.35	0.09	Eigenvalue	2.59	0.81	0.69	0.52	0.39
% of Variance	68.44	12.36	10.43	6.89	1.86	% of Variance	51.76	16.12	13.80	10.44	7.88
Cumulative Variance %	68.44	80.80	91.23	98.13	100.00	Cumulative Variance %	51.76	67.88	81.68	92.12	100.00
Unrotated Component Loadings						**Unrotated Component Loadings**					
iTRIMP	0.79	-	-	-	-	iTRIMP	0.74	-	-	-	-
sRPE	0.86	-	-	-	-	sRPE	0.74	-	-	-	-
Bodyload	0.79	-	-	-	-	Bodyload	0.68	-	-	-	-
HSD	0.84	-	-	-	-	HSD	0.72	-	-	-	-
Impacts	0.85	-	-	-	-	Impacts	0.71	-	-	-	-
Skills						**Strongman**					
Eigenvalue	2.38										
% of Variance	47.60	20.71	13.99	11.55	6.16	% of Variance	47.49	24.20	19.09	5.91	3.32
Cumulative Variance %	47.60	68.31	82.29	93.84	100.00	Cumulative Variance %	47.49	71.68	90.77	96.68	100.00
Rotated Component Loadings											
iTRIMP	-	0.88	-	-		**Rotated Component Loadings**	0.92	-	-	-	-
sRPE	-	0.77	-	-	-	sRPE	0.92	-	-	-	-
Bodyload	0.86	-	-	-	-	Bodyload	-	0.82	-	-	-
HSD	0.49	0.46	-	-	-	HSD	-	-	-	-	-
Impacts	0.87	-	-	-	-	Impacts	-	0.89	-	-	-
Speed						**Wrestle**					
Eigenvalue	2.32	1.02	0.86	0.48	0.33	Eigenvalue	2.21	1.31	0.93	0.42	0.13
% of Variance	46.38	20.34	17.16	9.51	6.62	% of Variance	44.28	26.26	18.51	8.42	2.53
Cumulative Variance %	46.38	66.72	83.88	93.39	100.00	Cumulative Variance %	44.28	70.54	89.05	97.47	100.00
Rotated Component Loadings						**Rotated Component Loadings**					
iTRIMP	0.82	-	-	-	-	iTRIMP	-	0.88	-	-	-
sRPE	0.86	-	-	-	-	sRPE	0.42	0.76	-	-	-

Bodyload	0.50	0.65	-	-	-	Bodyload	0.94	-	-	-	-
HSD	-	0.85	-	-	-	HSD	0.44	-	-	-	-
Impacts	0.50	0.45	-	-	-	Impacts	0.88	-	-	-	-

Table 3: Pearson correlations for each training load measure during each training mode, including 95% confidence intervals (CI) for each significant correlation. *significant at 0.05 level **significant at 0.001 level ***significant at 0.0001 level. Hopkins (2002) qualitative correlation descriptors: t: trivial (0-0.09), s: small (0.1-0.29), m: moderate (0.3-0.49), l: large (0.7-0.89), vl: very large (0.9-0.99). SSG: small-sided games; iTRIMP: individualised TRIMP; sRPE: session rating of perceived exertion; HSD: high-speed distance.

	Correlations									
	iTRIMP	**95% CI**	**sRPE**	**95% CI**	**Bodyload**	**95% CI**	**HSD**	**95% CI**	**Impacts**	**95% CI**
SSG										
iTRIMP	1.00	-	0.66*** l	[0.52-0.76]	0.62*** l	[0.47-0.73]	0.52*** l	[0.35-0.66]	0.50*** l	[0.32-0.64]
sRPE	-	-	1.00	-	0.43*** m	[0.24-0.59]	0.75*** vl	[0.64-0.83]	0.70*** vl	[0.57-0.79]
Bodyload	-	-	-	-	1.00	-	0.57*** l	[0.41-0.70]	0.69*** l	[0.56-0.79]
HSD	-	-	-	-	-	-	1.00	-	0.61*** l	[0.46-0.73]
Impacts	-	-	-	-	-	-	-	-	1.00	-
Conditioning										
iTRIMP	1.00	-	0.54*** l	[0.42-0.64]	0.62*** l	[0.52-0.70]	0.44*** m	[0.31-0.55]	0.33*** m	[0.19-0.46]
sRPE	-	-	1.00	-	0.28*** s	[0.14-0.41]	0.34*** m	[0.20-0.47]	0.34*** m	[0.20-0.47]
Bodyload	-	-	-	-	1.00	-	0.45*** m	[0.32-0.56]	0.41*** m	[0.28-0.53]
HSD	-	-	-	-	-	-	1.00	-	0.37*** m	[0.23-0.49]
Impacts	-	-	-	-	-	-	-	-	1.00	-
Skills										
iTRIMP	1.00	-	0.47*** m	[0.37-0.56]	0.26** s	[0.14-0.37]	0.30** m	[0.19-0.41]	0.14* s	[0.02-0.26]
sRPE	-	-	1.00	-	0.24*** s	[0.12-0.35]	0.32*** m	[0.21-0.42]	0.38*** m	[0.27-0.48]
Bodyload	-	-	-	-	1.00	-	0.38*** m	[0.27-0.48]	0.61*** l	[0.53-0.68]
HID	-	-	-	-	-	-	1.00	-	0.32*** m	[0.21-0.42]
Impacts	-	-	-	-	-	-	-	-	1.00	-
Speed										
iTRIMP	1.00	-	0.58*** l	[0.43-0.70]	0.31** m	[0.12-0.48]	0.08 t	-	0.15 s	-
sRPE	-	-	1.00	-	0.46*** m	[0.29-0.60]	0.16 s	-	0.46*** m	[0.29-0.60]
Bodyload	-	-	-	-	1.00	-	0.33*** s	[0.14-0.50]	0.46*** m	[0.29-0.60]
HSD	-	-	-	-	-	-	1.00	-	0.12 s	-
Impacts	-	-	-	-	-	-	-	-	1.00	-
Strongman										
iTRIMP	1.00	-	0.81*** vl	[0.70-0.88]	0.32* m	[0.07-0.53]	0.02 t	-	0.13 s	-
sRPE	-	-	1.00	-	0.48*** m	[0.26-0.65]	0.06 t	-	0.29* s	[0.04-0.51]
Bodyload	-	-	-	-	1.00	-	-0.55 l	-	0.68*** l	[0.51-0.80]
HSD	-	-	-	-	-	-	1.00	-	-0.66 l	-
Impacts	-	-	-	-	-	-	-	-	1.00	-
Wrestle										
iTRIMP	1.00	-	0.47** m	[0.19-0.68]	0.09 t	-	-0.09 t	-	-0.02 t	-

sRPE	-	-	1.00	-	0.45* m	[0.17-0.67]	0.04 t	-	0.35* m	[0.05-0.59]
Bodyload	-	-	-	-	1.00	-	0.28 s	-	0.83*** vl	[0.70-0.91]
HID	-	-	-	-	-	-	1.00	-	0.06 t	-
Impacts	-	-	-	-	-	-	-	-	1.00	-