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ORIGINAL INVESTIGATION

Combining Internal- and External-Training-Load Measures in Professional Rugby League

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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: individualized training impulse, session rating of perceived exertion; external—body load, high-speed distance, total impacts) were collected from 17 professional male rugby league players over the course of two 12-wk preseason periods. Training was categorized 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 1. Modes that extracted more than 1 principal component were subjected to a varimax rotation. ***Results:*** Small-sided games and conditioning extracted 1 principal component, explaining 68% and 52% of the variance, respectively. Skills, wrestle, strongman, and speed extracted 2 principal components each 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 1 individual measure. This would suggest that in training modes where 2 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, body load, high-speed running, impacts

Rugby league players engage in a diverse range of training modes to induce adaptations needed to succeed in competition.[1] However, given the interindividual variability in responses to any prescribed training session, it is imperative that sport scientists be able to use valid and reliable methods to monitor an individual's load during all training modes to optimize the training process.[1] At present, there are numerous methods used to monitor both the internal and external load, including heart-rate (HR) -based training-impulse (TRIMP) methods, session rating of perceived exertion (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 Banister's TRIMP ($r = .73$) and Edward's TRIMP ($r = .77$) 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 ($r = .80$) and player load ($r = .84$).[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 individualized physiological response to high-intensity intermittent activity.[4,5] As a result, the individualized 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 occasion include collision and contact episodes.[2] Differences in player load between training modes (skills, small-sided games, tactical, and match practice) have previously been described[6] that suggest that the training modality may influence the external loads that players are subjected to. Despite this, there is very limited information available in 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 is 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] While not the primary focus of that study, the training mode altered the strength of the relationships reported. For example, the association between sRPE and body load ranged from moderate ($r = .45$) during wrestling to large ($r = .64$) during skills conditioning.[2] Variation in the relationships between sRPE and other measures of load was also present among 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 differ in 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 (eg, 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 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] Depending on the training mode, it may be that training-load measures could be used interchangeably. Conversely, in certain modalities a combination of load measures

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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 among measures of training load to define common underlying dimensions in the variables via a principal-component analysis (PCA). PCA is a mathematical technique used to reduce the dimensionality of any given data set that consists of a number of highly correlated variables, while still keeping as much of the variation in the data set as possible.[9,10] We hypothesized that the different external-load structures of the various training modes would 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 years, height 186.0 ± 7.7 cm, mass 96.0 ± 9.3 kg, and first-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 at the University of Hull in accordance with the Declaration of Helsinki. Written informed consent was obtained from each player before 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 preseason preparatory periods during the 2011–12 and 2012–13 European Super League seasons.

Methodology

Training-load measures were assessed via microtechnology (HR, GPS, and in-built accelerometer) and the sRPE during each training session. Before the start of the study, all players were familiarized with these methods. The training program was prescribed by the Super League club coaching staff during the course of the study. During the study period, players typically completed 4 or 5 training sessions per week. Weekly sessions usually included 2 skills sessions, 2 conditioning sessions, and 1 skills-conditioning session. In addition, wrestle, speed, and strongman training were included in preexisting sessions on 2 occasions per week.

All sessions could be identified as 1 of the following training modes:

- Small-sided games: small-sided, high-intensity off-side and on-side conditioning games aimed to concurrently improve rugby-league-specific fitness and the execution of skills under fatigue.
- Conditioning: focus on high-intensity running and hill running aimed to improve players' aerobic fitness.
- Skills: focus on enhancing individual rugby league skills and team technical-tactical strategies.
- Speed: maximal-intensity running drills aimed to improve acceleration, speed, agility, and sprinting technique.
- Strongman: resistance training, which included compound movements of lifting and pulling unconventional objects, aimed to develop muscle hypertrophy and add an extra sense of competition and variety to the preseason preparatory period. Strongman sessions included tire pushes, flips, and Prowler pushes. The Prowler is a training sled that can be dragged or pushed with the option of adding resistance.
- 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 the Borg CR-10 scale,[12] which was collected ~30 minutes after the completion of each training session. sRPE was then multiplied by the training-session duration to calculate the sRPE training load in arbitrary units. All players who participated in the study had been familiarized with the RPE scale, including the interpretation of exertion in relation to the verbal anchors placed on 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 before the first test. The resting state included lying in a supine position in a quiet room. HR_{rest} was taken as the lowest 5-second value during the 5-minute monitoring period. Players then completed the staged incremental test on a motorized treadmill (Woodway ELG55, Woodway, Weil an Rhein, Germany) consisting of five 4-minute submaximal stages commencing at an initial running speed of 7 km/h with 1 minute recovery between stages. A finger capillary blood lactate sample was collected during the 1-minute recovery period and immediately analyzed in duplicate (YSI 2300, YSI Inc, Yellow Springs, OH). Treadmill speed was increased every stage by 2 km/h until a maximal speed of 15 km/h was reached. After this, a ramp protocol was used to determine the player's maximal HR (HR_{max}). The ramp protocol commenced at an initial speed of 15 km/h and increased at increments of 1 km/h per minute until volitional fatigue. HR data were collected throughout the treadmill test every 5 seconds using Polar HR straps (T14, Polar, Oy, Finland). The highest HR 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 as duration $\times \Delta HR \times ae^{bx}$, 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 his own data collected during the incremental treadmill test. HR was collected during each training session (every 5 s) using Polar HR straps (T14, Polar, Oy, Finland) that 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), body load, and total impacts were collected during each session. High-speed distance (>15 km/h), body load, 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 triaxial accelerometer data displayed in *g* force and sampling at 100 Hz were used to collect player body load and total impacts. Quantification of total impacts was derived from the summation of impacts in the vertical (*z*), mediolateral (*y*), and anteroposterior (*x*) planes. The magnitude of impacts was demarcated according to the following acceleration zones provided by the system manufacturer: 5.0 to 6.0 *g*, light impact (zone 1); 6.01 to 6.5 g, light to moderate impact (zone 2); 6.51 to 7.0 *g*, moderate to heavy impact (zone 3); 7.01 to 8.0 g, heavy impact (zone 4); 8.01 to 10.0 g, very heavy impact (zone 5); and >10.0 g, severe impact (zone 6). The impact counts within the 6 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 accelerations or 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 body load is an arbitrary measure of the total external mechanical stress as a result of accelerations, decelerations, changes of direction, and impacts. Player body load was calculated using the algorithm included in the software provided by the manufacturer (TeamAMS Version 16.1, GPSports, Canberra, Australia). Player body load is calculated from the square root of the sum of the squared instantaneous rate of change in acceleration in the vertical (*z*), anteroposterior (*x*), and mediolateral vectors (*y*). The magnitudes of the accelerations were classified into 6 zones (as described previously) with a factor (1–6 factor for zones 1–6) applied to each zone. Each player's body-load score was multiplied by the player's body mass, summed, and then expressed in arbitrary units.

Statistical Analysis

Before performing PCA, the Pearson correlation matrix was visually inspected to determine the factorability of the data for PCA.[19] The suitability of the data was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett test of sphericity.[21] KMO (~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 that the data set is suitable for PCA.[9,20] The Bartlett test of sphericity was significant for each training mode ($P < .001$). 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, while the principal components themselves do not correlate. Consequently, each principal component provides distinct information. The 5 training-load measures (iTRIMP, sRPE, body load, high-speed distance, and total impacts) were subjected to a PCA for each training mode using a prior communality estimate of less than 1. The stages involved in the calculation for a PCA are deletion of the mean, calculation of the covariance matrix of the data, determination of the eigenvalues and eigenvectors of the covariance matrix, and rotation of the original data onto a coordinate system spanned by the eigenvectors of the covariance matrix.[10] Rotation was performed when 2 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 1 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 17 players providing 42 ± 13 sessions each. Table 1 displays the number of sessions and mean training loads for each training mode.

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 2 principal components were identified for skills, speed, strongman, and wrestle training modes. Pearson correlations including 95% confidence intervals between the training-load methods for the different training modes are also presented in Table 3.

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

Discussion

The primary finding of the current study is the identification of more than 1 principal component for skills, speed, wrestle, and strongman training. For training modes where 2 principal components were

Table 1 Training-Load Measures and Session Durations During Each Training Mode, Mean ± SD

Training mode	n	Duration, min	iTRIMP, AU	sRPE, AU	Body load, AU	High-speed distance, m	Impacts, n
Small-sided games	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

Abbreviations: iTRIMP, individualized training impulse; sRPE, session rating of perceived exertion; AU, arbitrary unit.

Table 2 Results of the Principal-Component Analysis Showing the Eigenvalue, Percentage of Variance Explained, and Cumulative Percentage of Variance Explained by Each Principal Component (PC) for Each Training Mode, as Well as the Unrotated (1 PC Extracted) or Rotated (>1 PC Extracted) Training-Load Component Loadings for Each PC Extracted (PC Greater than the Eigenvalue-1 Criterion)

	Component				
Training mode	**1**	**2**	**3**	**4**	**5**
Small-Sided Games					
Eigenvalue	3.42	0.62	0.52	0.35	0.09
% of variance	68.44	12.36	10.43	6.89	1.86
Cumulative variance %	68.44	80.80	91.23	98.13	100.00
Unrotated component loadings					
individualized training impulse	0.79	—	—	—	—
session rating of perceived exertion	0.86	—	—	—	—
body load	0.79	—	—	—	—
high-speed distance	0.84	—	—	—	—
impacts	0.85	—	—	—	—
Skills					
Eigenvalue	2.38	1.03	0.70	0.58	0.31
% of variance	47.60	20.71	13.99	11.55	6.16
Cumulative variance %	47.60	68.31	82.29	93.84	100.00
Rotated component loadings					
individualized training impulse	—	0.88	—	—	—
session rating of perceived exertion	—	0.77	—	—	—
body load	0.86	—	—	—	—
high-speed distance	0.49	0.46	—	—	—
impacts	0.87	—	—	—	—
Speed					
Eigenvalue	2.32	1.02	0.86	0.48	0.33
% of variance	46.38	20.34	17.16	9.51	6.62
Cumulative variance %	46.38	66.72	83.88	93.39	100.00
Rotated component loadings					
individualized training impulse	0.82	—	—	—	—
session rating of perceived exertion	0.86	—	—	—	—
body load	0.50	0.65	—	—	—
high-speed distance	—	0.85	—	—	—
impacts	0.50	0.45	—	—	—
Conditioning					
Eigenvalue	2.59	0.81	0.69	0.52	0.39
% of variance	51.76	16.12	13.80	10.44	7.88
Cumulative variance %	51.76	67.88	81.68	92.12	100.00
Unrotated component loadings					
individualized training impulse	0.74	—	—	—	—
session rating of perceived exertion	0.74	—	—	—	—
body load	0.68	—	—	—	—
high-speed distance	0.72	—	—	—	—
impacts	0.71	—	—	—	—
Strongman					
Eigenvalue	2.37	1.21	0.85	0.30	0.17
% of variance	47.49	24.20	19.09	5.91	3.32
Cumulative variance %	47.49	71.68	90.77	96.68	100.00
Rotated component loadings					
individualized training impulse	0.92	—	—	—	—
session rating of perceived exertion	0.92	—	—	—	—
body load	—	0.82	—	—	—
high-speed distance	—	—	—	—	—
impacts	—	0.89	—	—	—
Wrestle					
Eigenvalue	2.21	1.31	0.93	0.42	0.13
% of variance	44.28	26.26	18.51	8.42	2.53
Cumulative variance %	44.28	70.54	89.05	97.47	100.00
Rotated component loadings					
individualized training impulse	—	0.88	—	—	—
session rating of perceived exertion	0.42	0.76	—	—	—
body load	0.94	—	—	—	—
high-speed distance	0.44	—	—	—	—
impacts	0.88	—	—	—	—

Table 3 Pearson Correlations (r) for Each Training Load Measure During Each Training Mode, Including 95% Confidence Intervals (CI) for Each Significant Correlation

	iTRIMP		sRPE		Body Load		HSD		Impacts	
	r	95% CI	r	95% CI	r	95% CI	r	95% CI	r	95% CI
SSG										
iTRIMP	1.00	—	.66^{***L}	[.52–.76]	.62^{***L}	[.47–.73]	.52^{***L}	[.35–.66]	.50^{***L}	[.32–.64]
sRPE	—	—	1.00	—	.43^{***M}	[.24–.59]	.75^{***VL}	[.64–.83]	.70^{***VL}	[.57–.79]
body load	—	—	—	—	1.00	—	.57^{***L}	[.41–.70]	.69^{***L}	[.56–.79]
HSD	—	—	—	—	—	—	1.00	—	.61^{***L}	[.46–.73]
impacts	—	—	—	—	—	—	—	—	1.00	—
Conditioning										
iTRIMP	1.00	—	.54^{***L}	[.42–.64]	.62^{***L}	[.52–.70]	.44^{***M}	[.31–.55]	.33^{***M}	[.19–.46]
sRPE	—	—	1.00	—	.28^{***S}	[.14–.41]	.34^{***M}	[.20–.47]	.34^{***M}	[.20–.47]
body load	—	—	—	—	1.00	—	.45^{***M}	[.32–.56]	.41^{***M}	[.28–.53]
HSD	—	—	—	—	—	—	1.00	—	.37^{***M}	[.23–.49]
impacts	—	—	—	—	—	—	—	—	1.00	—
Skills										
iTRIMP	1.00	—	.47^{***M}	[.37–.56]	.26^{**S}	[.14–.37]	.30^{**M}	[.19–.41]	.14^{*S}	[.02–.26]
sRPE	—	—	1.00	—	.24^{***S}	[.12–.35]	.32^{***M}	[.21–.42]	.38^{***M}	[.27–.48]
body load	—	—	—	—	1.00	—	.38^{***M}	[.27–.48]	.61^{***L}	[.53–.68]
HSD	—	—	—	—	—	—	1.00	—	.32^{***M}	[.21–.42]
impacts	—	—	—	—	—	—	—	—	1.00	—
Speed										
iTRIMP	1.00	—	.58^{***L}	[.43–.70]	.31^{**M}	[.12–.48]	.08^{T}	—	.15^{S}	—
sRPE	—	—	1.00	—	.46^{***M}	[.29–.60]	.16^{S}	—	.46^{***M}	[.29–.60]
body load	—	—	—	—	1.00	—	.33^{***S}	[.14–.50]	.46^{***M}	[.29–.60]
HSD	—	—	—	—	—	—	1.00	—	.12S	—
impacts	—	—	—	—	—	—	—	—	1.00	—
Strongman										
iTRIMP	1.00	—	.81^{***VL}	[.70–.88]	.32^{*M}	[.07–.53]	.02^{T}	—	.13^{S}	—
sRPE	—	—	1.00	—	.48^{***M}	[.26–.65]	.06^{T}	—	.29^{*S}	[.04–.51]
body load	—	—	—	—	1.00	—	–.55^{L}	—	.68^{***L}	[.51–.80]
HSD	—	—	—	—	—	—	1.00	—	–.66^{L}	—
impacts	—	—	—	—	—	—	—	—	1.00	—
Wrestle										
iTRIMP	1.00	—	.47^{**M}	[.19–.68]	.09^{T}	—	–.09^{T}	—	–.02^{T}	—
sRPE	—	—	1.00	—	.45^{*M}	[.17–.67]	.04^{T}	—	.35^{*M}	[.05–.59]
body load	—	—	—	—	1.00	—	.28^{S}	—	.83^{***VL}	[.70–.91]
HSD	—	—	—	—	—	—	1.00	—	.06T	—
impacts	—	—	—	—	—	—	—	—	1.00	—

Hopkins (2002) qualitative correlation descriptors: T, trivial (0–.09); S, small (.1–.29); M, moderate (.3–.49); L, large (.7–.89); VL, very large (.9–.99). Abbreviations: SSG: small-sided games; iTRIMP: individualized TRIMP; sRPE: session rating of perceived exertion; HSD: high-speed distance.

*Significant at .05 level. **Significant at .001 level. ***Significant at .0001 level.

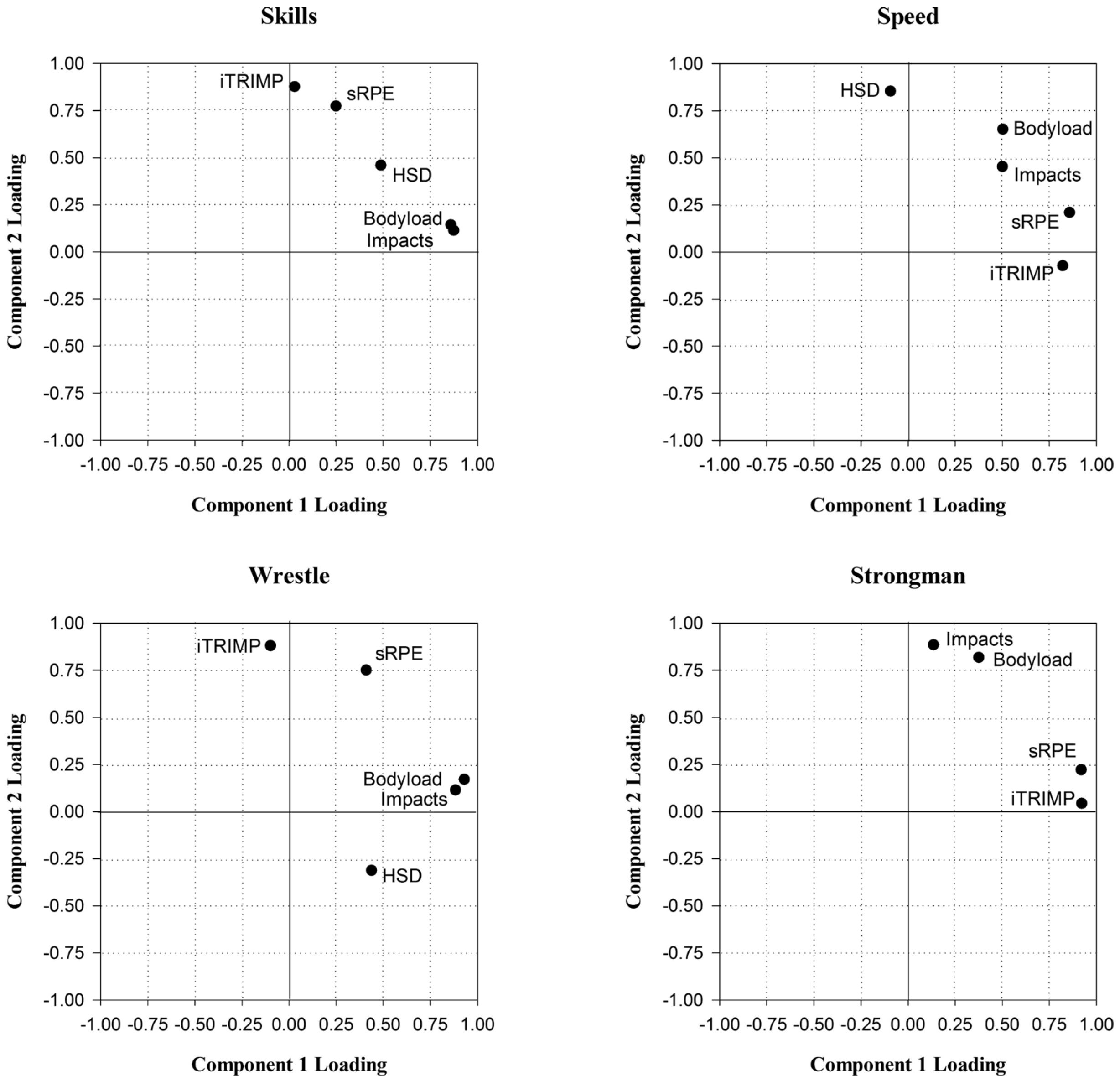

Figure 1 — Rotated component plots of the training modes where more than 1 principal component was retained for extraction. Abbreviations: HSD, high-speed distance; sRPE, session rating of perceived exertion; iTRIMP, individualized training impulse.

identified, the component loadings appear to align themselves with either internal- or external-load measures. For example, during skills training, the highest loadings for the first principal component are for body load (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 body load 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 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 that neither the internal nor external measures of load consistently explain the greatest amount of variance across modes of training. As a result, the use of 1 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 1 training mode may not do so in another training mode.

The presence of 2 principal components during skills training is potentially an important finding, as skills training can take up 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 than small-sided games and conditioning. Therefore, the use of 1 load measure in this training mode could potentially lead to a substantial underestimation of the training dose, which could affect team performance and injury risk. While the mechanisms behind the current findings are currently speculative, during skills training players spend a large proportion of their 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 1 external-load measure and 1 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 5 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 player loads/min) than open-skills training (10.5 player loads/min).[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 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 used.[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 than with the use of a single training-load measure. Finally, although previous research suggests that triaxial accelerometers in general show acceptable reliability,[6] further research is required to examine the reliability of the accelerometer and derived measures of body load and total impacts as used in 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 1 principal component identified, suggesting that a combination of both internal and external training-load measures is required to maximize the variance explained. During small-sided games and conditioning there was only a single principal component identified, which suggests that 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.

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