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**Abstract**

***Purpose*:** The aim of this study was to identify the dose-response relationship between measures of training load (TL) and changes in aerobic fitness in academy rugby union players. ***Method****:* Training data from ten academy rugby union players was collected during a six-week in-season period. Participants completed a lactate threshold (LT) test which was used to assess $VO_{2max}$ and velocities at $VO_{2max}$, 2 mmol·L$^{-1}$ (vLT) and 4 mmol·L$^{-1}$ (vOBLA) as measures of aerobic fitness. Internal training load measures calculated were Banister's TRIMP (bTRIMP), Edward's TRIMP (eTRIMP), Lucia's TRIMP (luTRIMP), individualised TRIMP (iTRIMP) and session-RPE (sRPE). External TL measures calculated were; total distance (TD), PlayerLoad™ (PL), high-speed distance >15 km·h$^{-1}$ (HSD), very high-speed distance >18 km·h$^{-1}$ (VHSD) and individualized high-speed distance based on each player's vOBLA (iHSD). ***Results:*** A second order regression (quadratic) analysis identified that bTRIMP ($R^2 = 0.78$, $P = 0.005$) explained 78% of the variance and iTRIMP ($R^2 = 0.55$, $P = 0.063$) explained 55% of the variance in changes in $VO_{2max}$. All other HR based internal TL measures and sRPE explained less than 40% of variance with fitness changes. External TL explained less than 42% of variance with fitness changes. ***Conclusions:*** In rugby players bTRIMP and iTRIMP display a curvilinear dose-response relationship with changes in maximal aerobic fitness.

**Keywords:** Training Impulse, GPS, Training Load, Blood lactate, Heart rate

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## Introduction

Rugby union is a high impact collision sport played over 80 minutes.[1] Games are typically aerobic in nature interspersed with frequent bouts of high-speed accelerations combined with high-impact collisions from tackles, scrums, rucks and mauls.[2] Aerobic fitness has previously been shown to be important for repeated sprint performance [3] and other characteristic of rugby match-play.[4] In semi-professional provincial-level players, progression into adolescence results in them typically training and competing for multiple teams each week.[5] The resulting high training loads (TL) could increase the risk of negative training response. [6] The physiological response relative to given training dose is commonly termed the dose-response relationship and is considered a fundamental component of training.[7] As part of the training process, the external TL provides coaches with an objective measure of physical activity completed for each session and match. The external TL when combined with the individual characteristics of the player determines the internal TL.[7] Ultimately it is the internal training load that determines the training outcome.[8] TL measures that demonstrate a strong dose-response relationship will provide coaches with a greater understanding of how players may respond to a given training stimulus.[9,10] These studies allow coaches/sports scientists to evaluate which load measures would be useful when looking at a particular training outcome. TL measures are often used to help manipulate the training dose, however if these TL measures fail to inform a strong enough dose-response relationship the manipulation of training using such measures may not result in expected training outcomes.[7]

The availability of Micro Electro Mechanical Systems/Global Positioning System (MEMS/GPS) and heart rate (HR) based systems in most professional rugby teams allows the monitoring of both external and internal TL. The use of HR as a measure of intensity is based on its linear relationship with oxygen consumption which is regarded as the gold standard measure of exercise intensity.[7] Although these systems and their derived measures have been reported in the rugby-specific literature, the focus to date has been on identifying potential differences in movement patterns based on position, age and different competition standards.[5] While research in rugby has reported use of HR-based Training Impulse (TRIMP) measures [11], session rating of perceived exertion (sRPE)[12] and external TL measures such as total distance and high-intensity distance, previous studies have focused on quantifying match activity profiles or associations between internal and external TL measures[2,13] rather than assessing dose-response relationships. Previous studies examining the validity of sRPE have observed large associations with HR-based measures [14] and very large associations with internal TL (Banister’s and Edward’s TRIMP) and external (Total distance, distance covered and time spent at low speed [<14.4 km·h$^{-1}$]) TL in professional soccer players.[15] However, an approach that demonstrates the dose-response relationship between TL and fitness rather than the correlation between TL methods has been advocated.[10,16] While HR-based methods have been used descriptively in Rugby[2,13], the fully individualised iTRIMP method which has shown preferential dose-response relationship with fitness in other sports [9,10,16-18] has not been examined in Rugby. However, one study that evaluated iTRIMP in rugby league using principle component analysis revealed that iTRIMP contributed to explaining the variance in different training modes as either the sole or one of two principle components.[11]

Additionally, the use of MEMS has advanced the area of monitoring external physical performance beyond distance and speeds to include tri-axial accelerometer based derivatives of external TL.[19] A vector-magnitude algorithm termed PlayerLoad™ (PL) is the most commonly used metric in the research literature. PL proposes the advantage of being able to track movements in all three planes of motion and has demonstrated reliability during Australian Football League match play (CV 1.9%).[20] Despite the plethora of TL studies conducted in Rugby using both internal and external TL, a study systematically evaluating of the dose-response relationship using all previously and newly used measures with fitness has yet to be conducted. Studies of this nature allow practitioners to ascertain which methods to employ for training monitoring for particular training outcomes. Therefore, the aim of this study was to examine the dose-response relationships between internal and external training load measures and changes in measures of aerobic fitness in academy rugby union players.

## Methods

### *Participants*

Ten academy rugby players (five forwards, and five backs) competing the current champions of the Association of Colleges Midland Elite League agreed to participate in the study (mean (*SD*) age: 18.4 (1.0) years, height: 181.3 (5.9) cm, body mass: 85.9 (13.0) kg, $VO_{2max}$: 56 (6.7) $mL \cdot kg^{-1} \cdot min^{-1}$). The academy team is a college based team aligned with a senior team competing in the National League One, which is two divisions below the English Premier League. Eight of the ten participants also trained and competed for their local rugby union club at under-18 or senior level. Players trained and played between four to six times per week. Training consisted of predominantly team-based tactical and skills training which included some physical conditioning, typically lasting 60 to 120 minutes. In addition, they played academy games on Wednesday and local club games on Saturday. The season starts in September and ends in January. The present six-week study was conducted from November to December. The participants were regular first team players, as such the participants played in all games. No additional top-up conditioning training was completed if players were substitutes. The study was granted institutional ethics approval prior to the commencement of the study and conformed to the declaration of Helsinki. Informed consent was provided by all players and where appropriate by parents (<18 years of age).

### *Physiological testing*

Prior to the start of the six week in-season study, the players completed a laboratory-based incremental exercise test. Participants avoided any strenuous exercise 48 hours prior to the test. Measurement of resting HR was taken prior to exercise (Polar T34, Polar Electro, OY, Finland). Participants were instructed on arrival to lie supine for ten minutes. The lowest 5 second HR was recorded as their resting heart rate ($HR_{rest}$). For the determination of heart rate – blood lactate relationships, maximal heart rate ($HR_{max}$), $VO_{2max}$ and velocity at $VO_{2max}$ ($vVO_{2max}$), participants completed an incremental test on a motorised treadmill (h/p cosmos mercury 4.0; h/p Cosmos, Nussdrof-Traunstein, Germany). The protocol consisted of six stages at 6, 8, 10, 12, 14 and 16 $km \cdot h^{-1}$.[10] Each stage was four minutes in duration with a one minute rest period between stages during which a fingertip capillary blood sample was taken and immediately analysed for blood lactate using a portable analyser (Lactate Pro, Arkray KDK, Japan).[21] One minute after completion of the six stages, participants completed a ramp protocol consisting of an increase in speed at a rate of 1 $km \cdot h^{-1} \cdot min^{-1}$ starting at 16 $km \cdot h^{-1}$. Participants were instructed to run until volitional exhaustion. HR data were recorded from a portable HR monitor (Polar T34, Polar Electro, OY, Finland). The mean HR in the final minute of each stage was used for subsequent analyses. Expired air was analysed continuously during the test using a breath-by-breath system (MetaLyzer 3B, Cortex Biophysik, Leipzig, Germany). The velocity at 2 $mmol \cdot L^{-1}$ (vLT) and at 4 $mmol \cdot L^{-1}$ (vOBLA) were also obtained as measures of aerobic fitness.[10]

*Training load*

TL was calculated using different methods based on HR, sRPE and MEMS/GPS metrics. They were measured for each player in every training session and competitive match for six weeks during the regular season, from November to December.

HR was measured using a short-range telemetry HR transmitter strap recording at 1 s intervals (Polar Team 2 System, Polar Electro Oy, Kempele, Finland). Raw HR data for each training session and match were exported into dedicated software to determine individual session iTRIMP and bTRIMP (iTRIMP Software, Training Impulse Ltd, UK) and bespoke spreadsheets were used for the calculation of eTRIMP and luTRIMP. bTRIMP was calculated based on training duration, HR, and a weighting factor using the following formula:

$$\text{bTRIMP} = \text{duration training (minutes)} \times \Delta HR \times 0.64e^{1.92x}$$

where $\Delta HR = (HR_{ex} - HR_{rest}) / (HR_{max} - HR_{rest})$, $e$ equals the base of the Napierian logarithms, 1.92 equals a generic constant for males and $x$ equals $\Delta HR$.[22]

eTRIMP [23] was calculated based on time spent in five HR zones and multiplied by a zone specific weighting factor: duration in zone 1 (50-59% of $HR_{max}$) multiplied by 1, duration in zone 2 (60-69% $HR_{max}$) multiplied by 2, duration in zone 3 (70-79% $HR_{max}$) multiplied by 3, duration in zone 4 (80-89% $HR_{max}$) multiplied by 4 and duration in zone 5 (90-100% $HR_{max}$) multiplied by 5. An adapted version of luTRIMP [24] was calculated by multiplying time spent in three HR zones based around HR at LT and OBLA; where duration in zone 1 (≤ HR at LT) is multiplied by weighing factor 1, duration in zone 2 (> HR at LT and < HR at OBLA) multiplied by 2 and duration in zone 3 (≥ HR at OBLA) multiplied by weighting factor 3. iTRIMP was calculated by weighting the exercise intensity for each individual's blood lactate response to incremental exercise, providing a weighting factor for each HR reading.

Total iTRIMP score of a training session is calculated by summating each iTRIMP score for each HR reading. The individual weighting factors were calculated for each participant based on their own HR – blood lactate relationship as per the method of Manzi et al.[9]

Approximately 30 minutes after each training session and match, players reported their RPE using the method of Foster et al.[12] Each player was asked how hard they found each training session or match, reporting their subjective perception of effort using the Borg 10-point category-ratio scale. Session-RPE was subsequently calculated as the RPE multiplied by the duration of the training session or match. Players were familiarised with the use of the RPE scale for a three-week period prior to the start of the six-week study period.

External training load was measured with a MEMS device (GPS 10 Hz, Tri-axial accelerometer 100Hz; Catapult S5, firmware 6.75, Catapult Innovations, Melbourne, Australia). The reliability of the GPS units has previously been demonstrated for the measurement of speed and distance in team sports (Varley et al., 2012). MEMS devices were switched on at least ten minutes prior to each training session and match to ensure a full satellite signal. Players were fitted with the same HR and MEMS device for each session. The MEMS device was placed in a pouch positioned between the players' scapulae. After every training session, the recorded data were downloaded onto a laptop using the manufacturer's software (Sprint 5.1, Catapult Innovations, Melbourne, Australia). External load measures were determined from GPS activity data. Activity was examined for total distance (TD) and distance covered at high-speed. Arbitrary pre-determined high-speed distance thresholds were set at $\geq 15 km \cdot h^{-1}$ (HSD) and $\geq 18 km \cdot h^{-1}$ (VHSD) in accordance with previous studies.[25] Additionally, each player's vOBLA (vOBLA ranged from 8.7 to $13.1 km \cdot h^{-1}$) was employed to set an individualised high-speed distance threshold (iHSD). A tri-axial piezoelectric linear accelerometer system allowed for measurement of PlayerLoad™ (PL) which is computed as a vector magnitude derived from the root mean square of accelerations recorded in the three principal axes of movement.

*Statistical analysis*

Prior to analysis the assumption of normality was verified by using the Shapiro-Wilk test. Descriptive statistics are presented as mean (standard deviation). Pre-and post-measures of fitness were compared using paired t-tests. Standardised effect size is reported as Cohen's *d*, using the pooled standard deviation as the denominator. Qualitative interpretation of *d* was based on the guidelines provided by Hopkins et al.[26]: 0 - 0.19 trivial; 0.20 – 0.59 small; 0.6 – 1.19 moderate; 1.20 – 1.99 large; ≥ 2.00 very large. Inferences about the true effect are based on the width of the confidence interval relative to the smallest worthwhile change (0.2 x standard deviation).[26] Visual inspection of the data between each measure of mean weekly TL and each measure of change in fitness suggested that the relationships with external load measures were linear while those with internal load measures were curvilinear. Dose-response relationships between the mean weekly internal TL and changes in fitness were determined using a second-order regression (quadratic) analysis.

Qualitative interpretation of the effect measure ($r^2$) was based on the percentage of the variance in the dependent variable explained by the internal TL measures. The dose-response relationship between mean weekly external TL and changes in fitness were determined using Pearson's product moment correlation coefficients. 99% confidence intervals in the coefficient of multiple regression and correlation coefficients are presented. The alpha was set at $P<0.01$ (CI at 99%) since the number of tests being conducted increases the risk of a false positive result. Qualitative interpretation of the relationships between weekly mean TL and changes in fitness were based on guidelines by Hopkins et al.[26]; were; 0-0.09 trivial; 0.1-0.29 small; 0.3-0.49 moderate; 0.50-0.69 large; 0.70-0.89 very large; 0.90-0.99 nearly perfect; 1.00 perfect. The probability that the magnitude of change was greater than the SWC was rated as; <0.5% almost certainly not; 0.5-5% very unlikely; 5-25% unlikely; 25-75% possibly; 75-95% likely; 95-99.5% very likely; >99.5% almost certainly. Where the probabilities of a substantial positive or negative change were both greater than 5%, the magnitude of change was described as unclear.[26] The Statistical Package for the Social Sciences (SPSS) (Version 23.0 for Windows; SPSS Inc, Chicago, IL) was used for analysis of the data.

## Results

During the six-week study period only two sets of data from two different players were missing, this was due to technical issues with the HR monitors. Missing data was replaced by taking an average from similar sessions for each individual. Internal and external load measures were obtained from a total 178 training and match observations for the ten participants during the six-week study period. During the study period players took part in 6 (2) matches, which included one regional 7's tournament and three Association of colleges elite league matches. Mean weekly training duration was 205 (96) minutes. The mean (SD) weekly internal training load (Arbitrary Units [AU]) for sRPE, bTRIMP, eTRIMP, luTRIMP and iTRIMP were 877 (273), 271 (97), 360 (104), 295 (92) and 479 (199), respectively. Mean weekly external load for TD (m), PL (AU), iHSD (m), 15HSD and 18HSD were 9939 (2989) m, 941 (324) AU, 3081 (844) m, 2317 (752) m and 738 (210) m respectively. Small changes in $VO_{2max}$ (ES: -037, unclear), vOBLA (ES: 0.36, likely positive), vLT (ES: 0.45, unclear) and a moderate change in $vVO_{2max}$ (ES: 0.65, likely positive) was observed in players during the six-week period (Table 1).

For internal training load measures bTRIMP identified a curvilinear relationship (Table 2, Figure 1a) and explained 78% of the variance in percentage changes in $VO_{2max}$ ($R^2 = 0.78$, $P = 0.005$). Improvement in the players' $VO_{2max}$ would peak at a mean weekly bTRIMP TL of approximately 226 (AU). Players with higher TL appear likely to experience a decrease in $VO_{2max}$ (Figure 1a). iTRIMP demonstrated a curvilinear relationship (Table 2, Figure 1b) and explained 55% of the variance in percentage changes in $VO_{2max}$ ($R^2 = 0.55$, $P = 0.063$). Improvement in the players' $VO_{2max}$ would peak at a mean weekly iTRIMP of approximately 406 (AU) (Figure 1b). As for the external training load measures, a large negative linear association was identified for 18HSD with both $VO_{2max}$ (r = -0.63 [99%CI: -0.90 to

0.58], $P = 0.051$, ES = large, 39% shared variance) and vOBLA (r = -0.66, [99%CI: -0.94 to 0.18], $P = 0.039$, ES = large, 43% shared variance) (Table 3). The 99% CI ranged from nearly perfect negative to small and a very likely negative association with $VO_{2max}$ and vOBLA. [26] For all other internal TL measures the variance explained was below 40% and external TL ranged from trivial to small associations (Tables 2 and 3).

## Discussion

The purpose of this study was to analyse the dose-response relationships between measures of internal and external TL and changes in fitness in academy rugby union players. The key finding of this study is that bTRIMP and iTRIMP are the measures of internal TL that explain 78% and 55% of the variance in changes in $VO_{2max}$ respectively. All other internal TL measures explained between 7% and 40% of the variance of the changes in fitness. It is interesting to note that these dose-response relationships are curvilinear rather than previously reported linear dose-response relationships. [9,10,16,17]

These findings are distinctive to those in youth soccer[10], senior soccer[18], hurling[27], running[9] and cycling[17]. These all showed linear dose-response relationships with changes in fitness. However, Manzi et al.[16] did report a curvilinear relationship between iTRIMP and autonomic nervous system responses. There are a couple of potential explanations for this. During this in-season six-week period the training was predominantly team tactics and skills based, with a limited number of specific conditioning sessions. This study groups training is in contrast to the more specific aerobic training prescribed in previous studies in endurance athletes[9] and soccer.[7,18] As such, the training stress recovery balance was potentially not optimal to stimulate aerobic training adaptations for all players in this study. This could be the reason why in previous studies, a linear relationship was found as the turn-point/optimum TL was yet to be reached. However, in rugby union due to the position specific demands and anthropometry, where backs are lighter and show greater aerobic fitness than forwards[28] similar training session still impose different internal loads for each player, which produce different levels of physiological stress. Therefore, in this situation we see a wide range of TL between players that enables us to elucidate curvilinear relationships should they exist better than in other sports.

In this cohort iTRIMP and bTRIMP demonstrates a curvilinear dose-response relationship with changes in $VO_{2max}$ showing that these are appropriate methods for monitoring internal TL in rugby union. Additionally, the second-order regression results estimated a mean weekly training load turn point of 226 (AU) for bTRIMP and 403 (AU) for iTRIMP. The turn point identifies the point at which further increases in training load would be predicted to lead to a decrease in fitness for these players. The optimal mean weekly load for this study group represented 83% (bTRIMP) and 84% (iTRIMP) of the groups mean weekly load. Our study findings question the use of those internal HR methods that use weightings in a linear manner (eTRIMP, luTRIMP) versus those that use exponential weightings based on physiological measures (bTRIMP, iTRIMP). It would appear that weightings being exponential are a critical factor for internal TL methods employed in Rugby Union to inform dose-response relationship with fitness. Furthermore, bTRIMP does not require extensive laboratory testing (although a $HR_{max}$ measurement is required) making it an easily applicable method. However, the dose-response relationship between iTRIMP and changes in fitness identified in soccer[10,18], running[9] and cycling[17] combined with our study findings in rugby consistently demonstrate the ability of iTRIMP to inform dose-response relationships with fitness across sports. sRPE explained less of the variance in the measured changes in fitness (7-14%), in line with other studies.[10,17] This is important to consider as much of the literature pertaining to the validity of sRPE emanates from its relationship with HR-based TL measures such as bTRIMP.[14] This approach has since been further utilized with external TL measures.[15] However, when the results of this study are examined, the explanation of the variance with the actual training outcomes for sRPE and bTRIMP are very different. Therefore, the use of an approach where one TL measure is correlated to another as validation must be questioned. One explanation for this could be the residual fatigue in players affecting RPE.[7]

Interestingly, we observed a large very likely negative relationship between very high speed distance (>18 $km \cdot h^{-1}$) and changes in $VO_{2max}$ and vOBLA. This suggests that when a greater proportion of time is spent at high-intensity distance in training, players are more likely to observe decreases in maximal aerobic fitness. The potential negative impact of VHSD could be linked to the decrease in $VO_{2max.}$ The four players who reported the largest mean weekly VHSD (917.6 ± 189.6) competed in a higher frequency of matches per week compared to the other players (1.3 vs. 0.9), also saw the largest decrease in $VO_{2max}$. For coaches' match-play potentially presents the greatest challenge in optimising players training stress and recovery balance. The very likely negative association between VHSD and change in $VO_{2max}$ and vOBLA are the first to be reported in the current literature, as such should be considered preliminary warranting further investigation. However, rugby union is a multifaceted contact-sport where several physiological capabilities are required including running at high speed and this may be more important than the potential impact on aerobic fitness. Research on maximal velocity exposures during a training week in Gaelic football has also shown negative consequences to high exposure[29]. All other external load measures demonstrated trivial to moderate, unclear relationships with our measures of fitness.

A limitation of the present study is the small sample size (n=10), although this is common in studies of athletes at this performance level. Sample size was also limited by the availability of MEMS devices, although the strength of the associations with such a small sample size shows the robustness of the objective TL measures. As a result of our findings, further seasonal longitudinal studies which consider how these relationships change in fatigued states, injury risk over pre and in-season periods. These studies will help us to better understand the nature of the dose-response relationships on an individual level.[22]

## Practical Applications

bTRIMP and iTRIMP are more suited for monitoring TL compared to internal TL methods such as luTRIMP and eTRIMP since they explain a larger percentage of the variance with changes in aerobic fitness in rugby union. As bTRIMP only requires a HRrest/max measurement for calculation, it may be more practical compared to iTRIMP, which requires threshold testing. The curvilinear relationships with internal TL measures and changes in fitness identified in this study further support the notion that increases in TL will eventually lead to negative training outcomes. The turn-points presented in this study give an objective measure of when negative consequences of training may start to predominate, this process can be applied to identify their own squad specific turn-point. VHSD and could be used to monitor external TL due to their negative dose-response relationship to changes in $VO_{2max}$ and vOBLA and can be viewed in context of other literature in team sports on exposure to high velocity activity.[29]

## Conclusions

This is the first study to the authors' knowledge to comprehensively examine the dose-response relationships between internal and external TL with aerobic fitness within rugby union. This study shows the superiority of bTRIMP and iTRIMP methods of internal TL, which employ an exponential weighting over methods that employ arbitrary linear weightings and sRPE. This study also shows, in contrast to previously reported dose-response relationships, curvilinear relationships for training load and changes in aerobic fitness.

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**"**The dose-response relationship between training load and aerobic fitness in academy rugby union players" by Taylor R, Sanders D, Myers T, Abt G, Taylor C, Akubat I.
*International Journal of Sports Physiology and Performance*


## Figures and tables

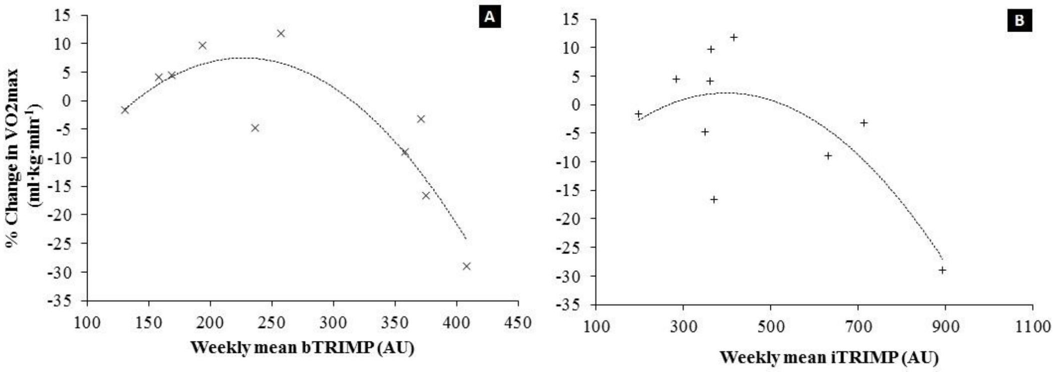


**Figure 1:** Second order regression (Quadratic) (A) between % change in $VO_{2max}$ and mean weekly bTRIMP ($R^2 = 0.78$; $P = 0.005$; Turn point = 226 AU). Regression coefficients: Intercept -41.9, 99%CL ± 80.1, $P = 0.11$; bTRIMP 0.44, 99%CL ± 0.66, $P = 0.05$. Second order regression (B) between % change $VO_{2max}$ and mean weekly iTRIMP ($R^2 = 0.55$, $P = 0.06$; Turn point = 406 AU). Regression coefficients: Intercept -18.2, 99%CL ± 72.9, $P = 0.41$; iTRIMP 0.1, 99%CL ± 0.3, P = 0.28.

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**Table 1.** Change in physiological fitness measures following six-week in-season period.

| | **Pre** Mean (SD) | **Post** Mean (SD) | **Mean difference** [99% CI] | **Cohen's d** | **Mechanistic Inference**[a] |
|---|---|---|---|---|---|
| **$VO_{2max}$** ($mL \cdot kg^{-1} \cdot min^{-1}$) | 56.2 (6.78) | 53.8 (6.16) | -2.40 [-9.86 – 5.06] | -0.37 (Small) | Unclear |
| **vVO2max** ($km \cdot h^{-1}$) | 14.9 (1.48) | 15.9 (1.45) | 0.95 [-2.41 – 0.51] | 0.65 (Moderate) | Very likely positive |
| **vOBLA** ($km \cdot h^{-1}$) | 10.4 (1.36) | 10.8 (0.9) | 0.42 [-1.20 – 0.36] | 0.36 (Small) | Likely positive |
| **vLT** ($km \cdot h^{-1}$) | 6.9 (0.9) | 7.3 (0.9) | 0.41 [-1.26 – 0.45] | 0.45 (Small) | Unclear |

Abbreviations: $VO_{2max}$; maximal oxygen uptake, $vVO_{2max}$; velocity at $VO_{2max}$, vOBLA; velocity at onset of blood lactate accumulation (4 $mmol \cdot L^{-1}$), vLT; velocity at lactate threshold (2 $mmol \cdot L^{-1}$).
a. With reference to a smallest worthwhile change of 0.2 x standard deviation.

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**Table 2.** Second-order regression (quadratic) results ($R^2$; 99% Confidence Intervals ($R^2$); *P*) between %Δ in aerobic fitness measures and mean weekly; internal training load (n = 10).

| | | **sRPE** (AU) | **iTRIMP** (AU) | **luTRIMP** (AU) | **eTRIMP** (AU) | **bTRIMP** (AU) |
|---|---|---|---|---|---|---|
| **%Δ $VO_{2max}$** | **$R^2$=** | **0.12** | **0.55** | **0.30** | **0.40** | **0.78*** |
| ($mL.kg^{-1}.min^{-1}$) | 99% CI = | -0.30 to 0.54 | 0.09 to 1.00 | -0.17 to 0.77 | -0.07 to 0.87 | 0.54 to 1.00 |
| | *P*= | *0.65* | *0.06* | *0.29* | *0.17* | *0.005* |
| **%Δ $vVO_{2max}$** | **$R^2$=** | **0.14** | **0.15** | **0.49** | **0.02** | **0.26** |
| ($km.h^{-1}$) | 99% CI = | -0.26 to 0.54 | -0.26 to 0.56 | 0.05 to 0.93 | -0.15 to 0.19 | -0.21 to 0.57 |
| | *P*= | *0.59* | *0.56* | *0.10* | *0.93* | *0.34* |
| **%Δ vOBLA** | **$R^2$=** | **0.07** | **0.04** | **0.02** | **0.27** | **0.21** |
| ($km.h^{-1}$) | 99% CI = | *-0.13 to 0.27* | *-0.20 to 0.28* | *-0.16 to 0.21* | *-0.25 to 0.79* | *-0.28 to 0.70* |
| | *P*= | *0.77* | *0.93* | *0.93* | *0.34* | *0.43* |
| **%Δ vLT** | **$R^2$=** | **0.11** | **0.22** | **0.2** | **0.11** | **0.31** |
| ($km.h^{-1}$) | 99% CI = | -0.29 to 0.51 | -0.28 to 0.72 | -0.29 to 0.53 | -0.29 to 0.51 | -0.21 to 0.83 |
| | *P*= | *0.66* | *0.41* | *0.46* | *0.65* | *0.26* |

Abbreviations: sRPE; session rating of perceived exertion, iTRIMP; individualised training impulse, eTRIMP; Edward's training impulse, bTRIMP; Banister's training impulse, arbitrary unit (AU).
*. Correlation is significant at the 0.01 level (2-tailed).

**Table 3.** Linear regression analysis results (r, effect size, 99% Confidence Interval, *P*, *mechanistic inference*) results between %Δ in aerobic fitness measures and mean weekly external training load (n=10). Interpretation of the strength of the correlation coefficient was based on guidelines provided by Hopkins et al.[26]

| | | **TD** (m) | **PL** (AU) | **iHSD** (m) | **15HSD** (m) | **18HSD** (m) |
|---|---|---|---|---|---|---|
| %Δ $VO_{2max}$ ($ml \cdot min \cdot kg^{-1}$) | **r** | **-0.51** | **-0.24** | **-0.26** | **-0.19** | **-0.63** |
| | ES | *Large* | *Small* | *Small* | *Small* | *Large* |
| | 99%CI | *-0.91 to 0.39* | *-0.84 to 0.62* | *-0.85 to 0.61* | *-0.82 to 0.65* | *-0.94 to 0.23* |
| | *P* | *0.13* | *0.50* | *0.47* | *0.59* | *0.05* |
| | Mechanistic Inference[a] | Unclear | Unclear | Unclear | Unclear | Very likely negative |
| %Δ $vVO_{2max}$ ($km \cdot h^{-1}$) | **r** | **-0.002** | **0.17** | **0.34** | **0.32** | **-0.16** |
| | ES | *Trivial* | *Small* | *Moderate* | *Moderate* | *Small* |
| | 99%CI | *-0.75 to 0.75* | *-0.67 to 0.82* | *-0.55 to 0.87* | *-0.57 to 0.86* | *-0.81 to 0.67* |
| | *P* | *0.99* | *0.64* | *0.33* | *0.36* | *0.66* |
| | Mechanistic Inference[a] | *Unclear* | *Unclear* | *Unclear* | *Unclear* | *Unclear* |
| %Δ vOBLA ($km \cdot h^{-1}$) | **r** | **-0.31** | **-0.47** | **0.27** | **0.25** | **-0.66** |
| | ES | *Moderate* | *Moderate* | *Small* | *Small* | *Large* |
| | 99%CI | *-0.86 to 0.57* | *-0.9 to 0.43* | *-0.61 to 0.85* | *-0.62 to 0.87* | *-0.94 to 0.18* |
| | *P* | *0.38* | *0.17* | *0.46* | *0.49* | *0.04* |
| | Mechanistic Inference[a] | *Unclear* | *Unclear* | *Unclear* | *Unclear* | *Very likely negative* |
| %Δ vLT ($km \cdot h^{-1}$) | **r** | **-0.21** | **-0.03** | **0.12** | **-0.06** | **-0.43** |
| | ES | *Small* | *Trivial* | *Small* | *Trivial* | *Moderate* |
| | 99%CI | *-0.83 to 0.64* | *-0.76 to 0.74* | *-0.70 to 0.8* | *-0.77 to 0.72* | *-0.89 to 0.47* |
| | *P* | *0.56* | *0.93* | *0.75* | *0.87* | *0.22* |
| | Mechanistic Inference[a] | *Unclear* | *Unclear* | *Unclear* | *Unclear* | *Unclear* |

Abbreviations; TD; total distance, PL; playerload™, iHSD; individualised high-speed distance based on players' velocity at OBLA; 15HSD; high-speed distance >15 $km \cdot h^{-1}$, 18HSD; high-speed distance >18 $km \cdot h^{-1}$, AU; arbitrary units.
*. Correlation is significant at the 0.01 level (2-tailed).