

## Relationship between different training impulses (TRIMP) in university handball athletes

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### Abstract:

**Problem Statement:** The motivation to increase performance or monitoring capacity shapes the findings and advances in the field. **Objective:** The objective was to evaluate the correlation between different training impulses and their relationship with isolated variables such as maximum heart rate (HRmax), lactate ([La-]<sub>b</sub>), glucose (GLU), rating of perceived exertion (PRE), the running time and the total number of repetitions. **Purpose:** This is a cross-sectional study. Twenty-four volunteers were recruited. They performed a strenuous exercise for the biceps brachii muscle with 75% of maximum repetition and the values of HRmax, [La-]<sub>b</sub> and glucose, rating of perceived exertion, execution time, and the total number of repetitions were collected. The Shapiro-Wilk test was used, followed by the Pearson (r) and Spearman (r<sub>s</sub>) correlation coefficients. The classification established by Munro for the magnitude of correlations was considered. **Results:** Total time seems to demonstrate a higher number of significant relationships with other measures, but with an outcome between weak and moderate (r/r<sub>s</sub> 0.408-0.821). HRmax was the variable with the lowest number of significant relationships. The TRIMP<sub>LAC</sub> and TRIMP<sub>GLU</sub> showed a strong relation relationship (r<sub>s</sub> 0.914). All TRIMPs presented at least a moderate relationship (0.70-0.89). **Conclusions:** Volunteers showed a moderate to a high correlation between TRIMP<sub>LAC</sub>, GLU, HR, and RPE. Compared to isolated load indices, the different TRIMPs showed impressive outcomes, especially for TRIMP<sub>LAC</sub> and TRIMP<sub>GLU</sub>. Thus, it is also possible to reproduce the method and the quality of the assessment for individuals who require practical and straightforward techniques in everyday life while remaining reliable for quantifying training demand.

**Key Words:** athletic performance; physical fitness; physical therapy modalities; fatigue; sports medicine.

### Introduction

The motivation for performance increase or even the ability to monitor it shapes the discoveries and advances in the area, whether for amateur or high-performance athletes. Appreciating the excellent performance of athletes is a pleasure for sport scientists. Watching a lousy performance inspires analysis of what went wrong and provides the basis for the issues that guide research in sport sciences (Foster et al., 2017).

Knowing that athletic or sports training is based on systematic exercise to improve physical skills and acquire specific sports skills, it is necessary to highlight the conditions for evaluating the demands promoted by such a process (Viru & Viru, 2000). Thus, one can have an internal load or external load (Coutts et al., 2018). While the external load can be exemplified by the total load lifted in work completed resistance training, e.g., the internal load can be given by indicators that reflect a psychophysiological response to the demands offered (Scott et al., 2016). Furthermore, as Impellizzeri et al. (2019) show, external and internal load concepts do not have a single measurement or a gold standard.

The excellent emphasis for proper preparation of athletes is related to the structuring and specifics of the training program, thus demonstrating direct interference of the professional and techniques employed. This way, the concept of training monitoring must be raised. Thus, the load measures essential indicators that reflect the actual psychophysiological response the body initiates to cope with the demands. The initial monitoring models were centered on a target heart rate, moving on to interval training and its relationship with the activity's execution time until the current internal and external load demands, with their respective representations (Foster et al., 2017; Impellizzeri et al., 2019).

A widely explored physiological parameter is Heart Rate (HR). It is validated to monitor intensity in different types of exercise and sports programs (Silva et al., 2018; Nagy et al., 2020). It presents a scientific structure and review, making it a relevant and practical tool to monitor fatigue in athletes (Schmitt et al., 2015). However, HR alone cannot quantify the external stressors that provoked a specific physiological response (Silva et al., 2018). The maximum heart rate (HRmax), i.e., the peak rate achieved in a specific test or imposed model,

seems to indicate the relative workload compared to the maximum load (Karvonen & Vuorimaa, 1988). Directly related to the HR parameter, the maximum value reached during a given demand has also been explored by the scientific literature. It was investigated together with the evaluation of modalities such as football (Silva et al., 2018; Radzimiński, 2021), beach handball (Pueo et al., 2017), among other modalities, showing itself as a tool for monitoring the individual's load and fatigue.

Also emphasized are the analyses for physiological variables monitored in blood samples, such as lactate ( $[La-]_b$ ) and glucose concentration. Thus,  $[La-]_b$  is one of the most frequent parameters during the clinical exercise test, as well as during the athlete performance test (Goodwin et al., 2007). Among the frequent uses, the response to progressive and incremental exercise in which the work rate is increased at regular intervals until the subject reaches voluntary exhaustion, respecting, along with the response of  $[La-]_b$  a gradual increase at the beginning, until an abrupt increase in the time of execution of the proposed exercise.

First described by Banister (1985) as a unit of physical exertion calculated using training duration and maximum, resting, and average HR during the exercise session, the Training Impulse (TRIMP) is often considered a valuable means of assessing training load. Thus, different ways of quantification can be explored. However, in light of our knowledge, few correlation studies between these results have been performed. Since internal and external load concepts are widespread and there is a clear relevance of these constructs within the training process, it is necessary to highlight athlete monitoring and discuss the knowledge limitations of their use as the current state of the art. It is known that when these systems are implemented effectively, there is a notable contribution to coaches and sports scientists to control and optimize the training process. So, given the need to evaluate and control demands, finding possible correlations between the proposed variables is of total importance, whether for predicting the state of high demand quickly or for costs, where the evaluator can use according to their reality of work or even for ease of application to the imposed environment. In this context, the objective of the study was to evaluate the correlation between different training impulses and also its relation with variables analyzed separately, such as maximum heart rate, lactate and glycemia, the rating of perceived exertion, the time of execution, and the total number of repetitions in handball university athletes.

## Material & methods

### Study Design

This is a cross-sectional study where a researcher was responsible for recruiting, assessing body composition, and testing maximum repetition. Two other researchers were responsible for the application of the fatigue protocol, blood lactate and glucose assessment, HR, application of the RPE scale, in addition to the execution time and the total number of repetitions, and a third researcher conducted the processing and analysis of the results of the collected data.

The study was conducted on two days of data collection. On the first day, the anamnesis and evaluation of body composition were conducted. On the second day, the muscle fatigue protocol was applied. The process can be seen in Figure 1. The study followed the STROBE Statement (von Elm et al., 2007), verifying the necessary items in cross-sectional study reports.

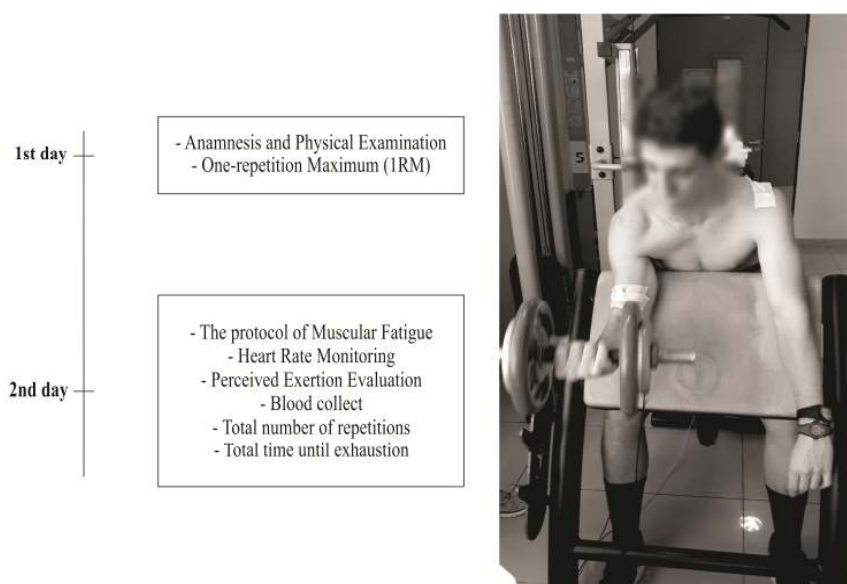


**Figure 1.** Flowchart of the data collection process and the protocol of muscular fatigue.

### *Ethics*

This study was approved in advance by the Ethics Committee of the Clinical Hospital of the Ribeirão Preto Medical School, University of São Paulo (protocol 3.130.366). The recruitment of participants took place directly with the team, where the invitation to participate was made verbally. Each participant voluntarily provided written informed consent before participating.

### *Participants*

Twenty-four male participants were recruited, included, and evaluated. The mean age was 22.31 (2.73) years; the mean Body Mass Index (BMI) was 29.00 (6.99), all were college handball players. According to the following inclusion criteria, the volunteers should not have reported musculoskeletal injury in the last three months, cardiovascular disease, respiratory disease, use of anti-inflammatory drugs and/or analgesics 72 hours before the evaluations, use of anabolic steroids, and use of alcohol and illegal drugs during the collection period.

### *Data sources/ measurement*

#### *Anamnesis and Physical Examination*

The evaluator collected the following data: personal data, weight (kg), height (m), BMI (kg/m<sup>2</sup>), previous diseases, use of medication, and history of surgery.

#### *One-repetition Maximum (1RM)*

Before starting, the athletes completed a warm-up and familiarization with the training, performing such execution briefly and with the load imposed by the bar itself, without additional weight. After the warm-up, the initial load was standardized at 30% of body mass. It could be increased or decreased until the maximum weight was recorded, lifted in a single movement without being able to perform a second repetition. A maximum of five attempts was made, and if a single repetition was not achieved, the highest value performed was considered (Felismino et al., 2014).

#### *The protocol of Muscular Fatigue*

The athletes were instructed to sit in the Scott chair, with the knee and hips flexed at 90° using a free dumbbell (Leal-Júnior et al., 2009) and perform the elbow flexion-extension movement, in the ranges of ±15° to ±70° of flexion with the shoulder stabilized, to avoid compensation in the movements. Before starting the muscular fatigue protocol, the athletes completed a warm-up, performing such execution for a brief moment and with the load imposed by the bar itself, without additional weight.

For the protocol, 75% of 1RM was defined for each volunteer, who accompanied a digital metronome (Cherub-WSM-001A) to control the movement speed at 60 bpm (1 second concentric/1 second eccentric). It was interrupted when the individual reached the state of concentric failure. That is, he was no longer able to perform the muscular action to overcome the imposed load or even when the individual failed twice in a row or three alternating to the speed pattern imposed by a sound stimulus.

This systematic training method collaborated with the observation of total work performed and exposure to the activity. Thus, for an accurate interpretation of time and number of repetitions, the athlete was filmed using a video camera (Smartphone X4, Motorola, São Paulo, Brazil), with 12 MP and 30 MHz. Subsequently, an analysis was performed in the Kinovea Video Editor software (<https://www.kinovea.org/>), a free and open-source video player for sports analysis. The athletes were previously instructed not to perform any vigorous exercise 24 hours before the collection and eat a bland diet at least two hours before the tests.

#### *Heart Rate (HR)*

The HR was monitored using an A300 watch (Polar Electro Oy, Kempele, Finland) with a heart rate monitor associated with a chest strap throughout the fatigue protocol. To record the values corresponding to baseline, the participants remained lying down for 10 minutes. The heart rate was analyzed during and after the proposed effort task, following the recovery times are up to 7 minutes after exercise.

#### *Rating of Perceived Exertion (RPE)*

It was performed with a score from 0 to 10, with 0 without any physical effort or sign and ten extremely strenuous activities, given the RPE, tension, discomfort, and/or fatigue (Robertson & Noble, 1997). It is used to assess relatively high muscle demands, thus offering high activity of the musculoskeletal, cardiovascular, and respiratory systems (Tiggemann et al., 2010).

#### *Lactate and Blood Glucose Analysis*

Blood lactate and blood glucose were collected before the protocol (baseline), immediately after completion, three, five, and seven minutes after exercise, where 25 µl of arterialized blood from the earlobe was collected in heparinized capillaries after cleaning the site with 70% ethyl alcohol and drying with cotton, and stored in an Eppendorf type polyethylene tube (1.5 mL) containing 50 µl of 1% sodium fluoride (NaF), for further analysis of lactacidemia (Buchheit et al., 2012), performed in a lactometer model 2300 Sport (Yellow Springs Instruments, Ohio, USA). Lactate values were expressed in mmol/L (Bastos et al., 2012), and blood glucose was presented in mg/dL.

#### *Estimation of internal training loads (TRIMP)*

Derivations of the initial TRIMP model proposed by Banister (1985) were explored. For our study, we explored the following equation:  $TRIMPx = variable\ a \times time$ , where  $x$  is the variable to be explored (for example, blood

lactate as  $TRIMP_{LAC}$ ), variable  $a$  is the variable collected in isolation (in this example, lactate), and  $time$  is the total time of exercise until exhaustion.

Thus, the data collected with the HRmax, the peak value of lactate and blood glucose, and the RPE were considered. Therefore, the product results between such variables and time were defined as  $TRIMP_{HR}$ ,  $TRIMP_{LAC}$ ,  $TRIMP_{GLU}$ , and  $TRIMP_{RPE}$ , respectively.

#### Study Size

The sample size calculation was performed with the Ene software, version 3.0 (Autonomous University of Barcelona, Barcelona, Spain). The estimate was based on detecting a moderate association ( $r = 0.6$ ), as suggested in the study by Coutts et al. (2009), along with the HR variables and RPE evaluation. Thus, it is estimated that some 21 participants will reach a statistical power of 90% and  $\alpha$  of 0.05. Twenty-four participants were recruited for this study, anticipating a possible 10% sample loss.

#### Statistical Methods

Initially, the distribution of data was analyzed using the Shapiro-Wilk test. Spearman's correlation ( $r_s$ ) was used when one of the non-parametric variables (Pre-exercise lactate, 3 Min Lactate, Blood Lactate Peak, RPE, and  $TRIMP_{GLU}$ ) were being analyzed. For the others ( $TRIMP_{LAC}$ ,  $TRIMP_{HR}$ ,  $TRIMP_{RPE}$ , Total number of repetitions, Total execution time, Post-exercise Lactate, and Lactate 5 and 7 Min, Glucose Pre and exactly Post-exercise, 3, 5, 7 Min and Blood Glucose Peak), Pearson's correlation test ( $r$ ) was used.

The classification established by Munro (2001) was used to interpret the magnitude of the correlations: 0.26 to 0.49, weak; 0.50 to 0.69, moderate; 0.70 to 0.89, high; and 0.90 to 1.00, very high. Data processing was performed using the GraphPad Prism software (GraphPad Software) version 7.0, with a 5% significance level.

#### Results

Twenty-four male participants were evaluated. For the central tendency values and the dispersion of the study variables, see Table 1.

**Table 1.** Description of the Mean Values, SD, Median, and First and Third Quartiles of the Study's Variables ( $n = 24$ ).

| Outcomes                          | Mean   | SD    | Median | 1 <sup>st</sup> Quartile | 3 <sup>rd</sup> Quartile |
|-----------------------------------|--------|-------|--------|--------------------------|--------------------------|
| Maximum Heart Rate (pps)          | 108.20 | 23.33 | 103    | 96.5                     | 126.8                    |
| Total number of repetitions       | 17.21  | 6.57  | 17     | 12                       | 21.75                    |
| Total work completed (kg)         | 411.9  | 150.4 | 397    | 302                      | 508.5                    |
| Total time until exhaustion (sec) | 37.96  | 10.50 | 38.5   | 30                       | 44.25                    |
| Blood Lactate (mmol/L)            |        |       |        |                          |                          |
| Pre-exercise                      | 1.16   | 0.40  | 1.06   | 0.82                     | 1.44                     |
| Post-immediate                    | 1.47   | 0.53  | 1.40   | 1.04                     | 1.96                     |
| Post-3 Min                        | 2.22   | 0.61  | 2.15   | 1.78                     | 2.60                     |
| Post-5 Min                        | 2.16   | 0.55  | 2.26   | 1.59                     | 2.41                     |
| Post- 7 Min                       | 1.99   | 0.60  | 1.97   | 1.54                     | 2.35                     |
| Peak                              | 2.31   | 0.58  | 2.30   | 1.79                     | 2.65                     |
| Blood Glucose (mg/dL)             |        |       |        |                          |                          |
| Pre-exercise                      | 84.10  | 14.87 | 86.7   | 72.38                    | 95.63                    |
| Post-immediate                    | 87.61  | 14.32 | 86.4   | 79.28                    | 97.88                    |
| Post-3 Min (mg/dL)                | 90.15  | 17.38 | 90.15  | 79.43                    | 103.4                    |
| Post-5 Min (mg/dL)                | 91.37  | 10.65 | 89.7   | 81                       | 99.3                     |
| Post-7 Min (mg/dL)                | 90.33  | 13.23 | 90     | 79.88                    | 101.6                    |
| Peak-(mg/dL)                      | 95.81  | 12.62 | 95.1   | 83.63                    | 106.1                    |
| RPE                               | 7.88   | 1.78  | 8      | 7                        | 9.75                     |
| $TRIMP_{RPE}$                     | 292.9  | 88.37 | 298    | 206                      | 363.8                    |
| $TRIMP_{LA}$                      | 90.18  | 38.39 | 92.75  | 55.8                     | 112.3                    |
| $TRIMP_{GLU}$                     | 3705   | 1403  | 3346   | 2574                     | 4313                     |
| $TRIMP_{HR}$                      | 4138   | 1569  | 3710   | 2940                     | 5168                     |

SD: Standard Deviation; pps: pulse per second; kg: kilogram; sec: seconds; mmol/L: millimole per liter; mg/dL: millimole per deciliter; RPE: Rating of Perceived Exertion

Only the internal and external load quantification variables were analyzed with their respective relationships. Thus, the total exercise time seems to demonstrate a greater number of statistically significant relationships with other measures, but with an outcome between weak and moderate. HRmax is the variable with the lowest number of significant relationships among the ones explored (Table 2). Also, for the different evaluations in front of HRmax,  $[La-]_b$ , glucose and RPE (internal load), and total work, the number of repetitions and time to exhaustion (external load) did not show statistically significant indices.

The  $TRIMP_{LAC}$  and  $TRIMP_{GLU}$  showed a strong relationship, as expected by the intimate physiological bond. Furthermore, it should be noted that all TRIMPs presented at least a moderate association with statistical significance (Table 3).

**Table 2.** Correlation between different evaluation of internal and external loads (n = 24).

| Outcomes       | HRmax        |          | RPE          |            | Number of reps |               | Total Work  |            | Total Time  |            |
|----------------|--------------|----------|--------------|------------|----------------|---------------|-------------|------------|-------------|------------|
| HRmax          | -            | -        | -            | -          | -              | -             | -           | -          | -           | -          |
| RPE            | $r_s -0.077$ | $p 0.72$ | -            | -          | -              | -             | -           | -          | -           | -          |
| Number of reps | $r 0.183$    | $p 0.39$ | $r_s -0.192$ | $p 0.37$   | -              | -             | -           | -          | -           | -          |
| Total work     | $r 0.168$    | $p 0.43$ | $r_s 0.027$  | $p 0.90$   | $r 0.778$      | $p <0.0001^*$ | -           | -          | -           | -          |
| Total time     | $r 0.134$    | $p 0.53$ | $r_s -0.327$ | $p 0.12$   | $r 0.821$      | $p <0.0001^*$ | $r 0.512$   | $p 0.01^*$ | -           | -          |
| Blood Lactate  |              |          |              |            |                |               |             |            |             |            |
| Pre-exercise   | $r_s 0.125$  | $p 0.56$ | $r_s -0.354$ | $p 0.09$   | $r_s 0.080$    | $p 0.71$      | $r_s 0.191$ | $p 0.37$   | $r_s 0.233$ | $p 0.27$   |
| Post-immediate | $r -0.055$   | $p 0.80$ | $r_s -0.095$ | $p 0.66$   | $r 0.425$      | $p 0.04^*$    | $r 0.335$   | $p 0.11$   | $r 0.451$   | $p 0.03^*$ |
| Post-3 Min     | $r_s 0.278$  | $p 0.19$ | $r_s -0.397$ | $p 0.05$   | $r_s 0.237$    | $p 0.26$      | $r_s 0.402$ | $p 0.05$   | $r_s 0.459$ | $p 0.02^*$ |
| Post-5 Min     | $r 0.155$    | $p 0.48$ | $r_s -0.213$ | $p 0.33$   | $r 0.441$      | $p 0.04^*$    | $r 0.526$   | $p 0.01^*$ | $r 0.455$   | $p 0.03^*$ |
| Post-7 Min     | $r 0.187$    | $p 0.38$ | $r_s -0.159$ | $p 0.46$   | $r 0.461$      | $p 0.02^*$    | $r 0.475$   | $p 0.02^*$ | $r 0.515$   | $p 0.01^*$ |
| Peak           | $r_s 0.251$  | $p 0.24$ | $r_s -0.296$ | $p 0.16$   | $r_s 0.408$    | $p 0.05^*$    | $r_s 0.509$ | $p 0.01^*$ | $r_s 0.586$ | $p 0.00^*$ |
| Blood Glucose  |              |          |              |            |                |               |             |            |             |            |
| Pre-exercise   | $r -0.343$   | $p 0.10$ | $r_s -0.284$ | $p 0.18$   | $r 0.029$      | $p 0.89$      | $r 0.053$   | $p 0.80$   | $r 0.337$   | $p 0.11$   |
| Post-immediate | $r -0.233$   | $p 0.27$ | $r_s -0.454$ | $p 0.03^*$ | $r 0.252$      | $p 0.24$      | $r 0.091$   | $p 0.67$   | $r 0.403$   | $p 0.05$   |
| Post-3 Min     | $r -0.266$   | $p 0.21$ | $r_s -0.345$ | $p 0.10$   | $r 0.036$      | $p 0.87$      | $r 0.061$   | $p 0.78$   | $r 0.265$   | $p 0.21$   |
| Post-5 Min     | $r -0.068$   | $p 0.76$ | $r_s -0.451$ | $p 0.03^*$ | $r 0.401$      | $p 0.06$      | $r 0.229$   | $p 0.29$   | $r 0.454$   | $p 0.03^*$ |
| Post-7 Min     | $r -0.178$   | $p 0.40$ | $r_s -0.357$ | $p 0.09$   | $r 0.362$      | $p 0.08$      | $r 0.256$   | $p 0.23$   | $r 0.484$   | $p 0.02^*$ |
| Peak           | $r -0.227$   | $p 0.29$ | $r_s -0.335$ | $p 0.11$   | $r 0.380$      | $p 0.07$      | $r 0.248$   | $p 0.24$   | $r 0.532$   | $p 0.01^*$ |

HRmax: Heart rate maximum; RPE: Rating of Perceived Exertion; Number of reps: Total number of repetitions; Total work: Total work completed (kg); Total time: Total time until exhaustion (sec); r: Pearson correlation coefficient;  $r_s$ : Spearman correlation coefficient; \*Statistically significant association.

**Table 3.** Correlation between TRIMP<sub>LA</sub>, TRIMP<sub>GLU</sub>, TRIMP<sub>HR</sub>, and TRIMP<sub>RPE</sub> (n = 24).

| Outcomes             | TRIMP <sub>LA</sub> |               | TRIMP <sub>RPE</sub> |            | TRIMP <sub>HR</sub> |               |
|----------------------|---------------------|---------------|----------------------|------------|---------------------|---------------|
| TRIMP <sub>LA</sub>  | -                   | -             | -                    | -          | -                   | -             |
| TRIMP <sub>RPE</sub> | $r 0.532$           | $p 0.01^*$    | -                    | -          | -                   | -             |
| TRIMP <sub>HR</sub>  | $r 0.679$           | $p 0.00^*$    | $r 0.532$            | $p 0.01^*$ | -                   | -             |
| TRIMP <sub>GLU</sub> | $r_s 0.914$         | $p <0.0001^*$ | $r_s 0.587$          | $p 0.00^*$ | $r_s 0.741$         | $p <0.0001^*$ |

r: Pearson correlation coefficient;  $r_s$ : Spearman correlation coefficient; \*Statistically significant association.

The relationship between the different TRIMPs and the other demand as internal and external load quantification variables was analyzed and presented in Table 4. The relationship between TRIMP<sub>LAC</sub> and TRIMP<sub>GLU</sub> with these variables is emphasized. The HRmax, the total number of repetitions, the total time to exhaustion, different points of the lactate and glucose curve, besides the RPE and total work, were considered for analysis. Finally, the TRIMP<sub>RPE</sub> was the one that presented the lowest relation in strength and quantity of statistically significant related variables.

**Table 4.** Correlation between TRIMPs and different variables analyzed (n = 24).

| Outcomes       | TRIMP <sub>LA</sub> |               | TRIMP <sub>GLU</sub> |               | TRIMP <sub>HR</sub> |               | TRIMP <sub>RPE</sub> |            |
|----------------|---------------------|---------------|----------------------|---------------|---------------------|---------------|----------------------|------------|
| HRmax          | $r 0.122$           | $p 0.57$      | $r_s 0.058$          | $p 0.79$      | $r 0.707$           | $p 0.00^*$    | $r 0.146$            | $p 0.50$   |
| Number of reps | $r 0.721$           | $p <0.0001^*$ | $r_s 0.668$          | $p 0.00^*$    | $r 0.713$           | $p <0.0001^*$ | $r 0.636$            | $p 0.00^*$ |
| Total work     | $r 0.556$           | $p 0.00^*$    | $r_s 0.435$          | $p 0.03^*$    | $r 0.467$           | $p 0.02^*$    | $r 0.517$            | $p 0.01^*$ |
| Total time     | $r 0.882$           | $p <0.0001^*$ | $r_s 0.907$          | $p <0.0001^*$ | $r 0.782$           | $p <0.0001^*$ | $r 0.631$            | $p 0.00^*$ |
| Blood Lactate  |                     |               |                      |               |                     |               |                      |            |
| Pre-exercise   | $r_s 0.560$         | $p 0.00^*$    | $r_s 0.401$          | $p 0.05$      | $r_s 0.253$         | $p 0.23$      | $r_s 0.047$          | $p 0.83$   |
| Post-immediate | $r 0.658$           | $p 0.00^*$    | $r_s 0.523$          | $p 0.01^*$    | $r 0.281$           | $p 0.18$      | $r 0.397$            | $p 0.05$   |
| Post-3 Min     | $r_s 0.803$         | $p <0.0001^*$ | $r_s 0.628$          | $p 0.00^*$    | $r_s 0.491$         | $p 0.01^*$    | $r_s 0.133$          | $p 0.53$   |
| Post-5 Min     | $r 0.780$           | $p <0.0001^*$ | $r_s 0.702$          | $p 0.00^*$    | $r 0.402$           | $p 0.06$      | $r 0.344$            | $p 0.11$   |
| Post-7 Min     | $r 0.820$           | $p <0.0001^*$ | $r_s 0.682$          | $p 0.00^*$    | $r 0.477$           | $p 0.02^*$    | $r 0.429$            | $p 0.04^*$ |
| Peak           | $r_s 0.886$         | $p <0.0001^*$ | $r_s 0.704$          | $p 0.00^*$    | $r_s 0.594$         | $p 0.00^*$    | $r_s 0.330$          | $p 0.12$   |
| Blood Glucose  |                     |               |                      |               |                     |               |                      |            |
| Pre-exercise   | $r 0.499$           | $p 0.01^*$    | $r_s 0.516$          | $p 0.01^*$    | $r 0.036$           | $p 0.87$      | $r -0.096$           | $p 0.65$   |
| Post-immediate | $r 0.571$           | $p 0.00^*$    | $r_s 0.566$          | $p 0.00^*$    | $r 0.150$           | $p 0.49$      | $r -0.048$           | $p 0.82$   |
| Post-3 Min     | $r 0.439$           | $p 0.03^*$    | $r_s 0.539$          | $p 0.01^*$    | $r 0.036$           | $p 0.87$      | $r -0.124$           | $p 0.56$   |
| Post-5 Min     | $r 0.566$           | $p 0.00^*$    | $r_s 0.597$          | $p 0.00^*$    | $r 0.297$           | $p 0.17$      | $r 0.006$            | $p 0.98$   |
| Post-7 Min     | $r 0.603$           | $p 0.00^*$    | $r_s 0.681$          | $p 0.00^*$    | $r 0.261$           | $p 0.22$      | $r 0.197$            | $p 0.36$   |
| Peak           | $r 0.683$           | $p 0.00^*$    | $r_s 0.725$          | $p <0.0001^*$ | $r 0.256$           | $p 0.23$      | $r 0.170$            | $p 0.43$   |
| RPE            | $r_s -$             |               | $r_s -$              |               | $r_s -0.367$        | $p 0.08^*$    | $r_s 0.367$          | $p 0.08$   |
|                | $0.330$             | $p 0.12$      | $0.306$              | $p 0.15$      |                     |               |                      |            |

HRmax: Heart rate maximum; Number of reps: Total number of repetitions; Total work: Total work completed (kg); Total time: Total time until exhaustion (sec); RPE: Rating of Perceived Exertion; r: Pearson correlation coefficient;  $r_s$ : Spearman correlation coefficient; \*Statistically significant association.

## Discussion

The training impulse (TRIMP) concept has gained notoriety and advancement to the practical and scientific literature. However, its relationship with other quantifications of the load is still uncertain. Thus, the relationship analysis between the most used tools was developed in our study, demonstrating important correlations between the TRIMP<sub>LAC</sub>, GLU, HR, and RPE. When analyzed in isolated ways, only the variables as the number of repetitions, work, and total time showed significant results, but with weak or moderate correlations. As shown by Foster et al. (2017), the simplicity and applicability of this tool should be highlighted and thus, from our findings, present a relationship between the different TRIMPs can also favor as a tool for measuring the state of high demand quickly in addition to being adaptable to different financial realities, where the evaluator can use according to their working condition or even the ease of application to the imposed environment.

Foster (1998) demonstrated the individual correlation rates of moderate to strong between RPE and HR. However, our findings, when analyzed in isolation, do not show a correlation within them. However, in a TRIMP<sub>HR</sub> vs. TRIMP<sub>RPE</sub> condition, there is a moderate and significant relationship ( $r_s = 0.587$ ). Also, Impellizzeri et al. (2004) showed weak to moderate correlations between the session RPE and TRIMP methods in soccer players during training and matches. Thus, they corroborate our findings, with a moderate level result. It should be noted that the difference in the stimulus offered by the studies may have interfered with the magnitude of the outcome.

The analyses across different evaluations of internal (HRmax, [La-]<sub>b</sub>, glucose, and RPE) and external loads (Total work, number of repetitions, and time until exhaustion) did not present statistically significant indices. Part of this is due to the differences within these variables depending on factors such as the intensity and duration of the effort to which the individual was exposed (da Silva et al., 2003) since exercise intensity is one of the essential variables controlling training. Rafo et al. (2008) presented an analysis of blood lactate, HR, and RPE in bench press exercise, achieving a high correlation between them, unlike what was found in the present study. Demonstrating the possibility of interference from the intensity of the activity evaluated, duration times, or even methodological aspects, such as the low number of individuals included for analysis. Therefore, the analysis of different TRIMPs may be a point to be evaluated under conditions highlighted as different intensities, environments, and exercises. As well as the imposed intensity conditions, specific conditions such as gender and competitive level may suggest a high variability of HR data in pre- and post-activity conditions (Djordjevic et al., 2012). However, the present does not have the bias of variation due to gender and competitive level. All those evaluated were male biologicals and classified at the college level of competition.

Various populations can benefit from different load and demand analyses. Perret et al. (2012) developed a study with wheel-chair users, where the protocol included analyses of minimum and maximum stationary lactate under different conditions and RPE assessment. Different from our data indicated, a strong correlation between HR at minimum or maximum lactate state after exercise was observed. However, a significant difference in this study is that the participants have spinal cord injuries compared to unaffected individuals and have metabolic, musculoskeletal, neuromuscular, cardiorespiratory, and thermoregulatory abnormalities, which interfere with the correlations (West & Krassioukov, 2017).

The development of new methods or proposals such as those discussed here can improve interaction with the data quickly and financially adaptable. The knowledge and application of such methods still need progress, as demonstrated in a recent article by Ulmer and collaborators (2019). The group aimed to improve a tool sensitive to quantifying changes in the training load, having seen different stimuli offered by various sports available. The concept of TRIMP is suitable to quantify moderate changes in the training load. However, improving methods is attractive, using other loads and demands and defining the best methods of acquiring physiological variables. Cerda-Kohler et al. (2016) conducted a study with professional soccer athletes, along with lactate analysis, using four different forms of interaction with these results. Thus, there was no correlation between the methods analyzed to determine the threshold in the different views. So, different forms of analysis were not predominant factors for higher loyalty of the results. It should also be considered that, although no high and significant relations between isolated variables have been observed, to analyze in front of the equation proposed here seems to be a way out, increasing both the number and the outcome of these relations significantly. As well, external technologies can be associated not only with physiological analysis but also with external demands, as proposed by Izzo et al. (2018). Although our study presents the limitation of not exploring different age groups or even different sexes, the findings can be analyzed as initial interest results to the performance analysis community.

## Conclusions

University handball athletes showed a moderate to a high correlation between TRIMP<sub>LAC</sub>, GLU, HR, and RPE. Compared to isolated load indices, the different TRIMPs showed impressive outcomes, especially for TRIMP<sub>LAC</sub> and TRIMP<sub>GLU</sub>. The isolated load indices as maximum heart rate, blood lactate, blood glucose, RPE scale, execution time, and the total number of repetitions in strenuous exercise for the biceps brachii muscle do not present high outcomes as showed by TRIMPs. This way, it is also possible to reproduce the method and the evaluation quality for individuals who require practical and straightforward techniques. Thus, accounting for

more easily accessible factors associated with the time of exposure to exercise can be considered a valuable and reliable way to quantify the demand for training.

To the practical aspect and directed to the demand control professional, one must have that the total exercise time seems to show a larger number of statistically significant relationships with other measures, especially when considered as TRIMP in its equation. Thus, if available to the application environment, the best relationship indexes between the variables were given for the blood magnitudes (lactate and glucose), followed by the lower cost ones, heart rate, and RPE, respectively. Thus, they show themselves as important tools for field practice, but not at their highest standard.

**Conflicts of interest** - The authors declare that they have no conflicts of interest concerning this article.

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