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PSYCHOLOGICAL LOAD RELATED TO TRAINING AND COMPETITIONS IN ATHLETES: VALIDITY AND RELIABILITY OF NEW DIFFERENTIAL RPE SCALES

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INDEX

Abstract

The purpose of this PhD thesis was to begin the validation process of two RPE-based scales that separate the psychological load of a training session from the physical one. Five different studies were conducted with more than two hundred semi-professional and élite athletes. The two new differential RPE scales, the perceived mental exertion rating scale (M-RPE) and the perceived physical exertion sclae (P-RPE), results valid compared to the criterion measure, able to discriminate different mental and physical training loads in field and in laboratory environment, and very reliable with athletes on the field. Finally, the ecological validity of the two scales was tested in a pilot study in which 4 professional and semi-professional teams were monitored differentiating the perceived effort experienced by athletes during training and competitions. The results of this multiple research studies support the use of differential RPE scales in the daily practice of monitoring the training loads of individual and team sports athletes. Finally we provided reliable and ecologically valid measures of physical and mental loads in different types of training and competition.

Keywords: Psychological Load, Mental-RPE, Physical-RPE, athletes, discriminant validity, ecological validity

Overview of the thesis

In this PhD thesis, the mechanism of fatigue applied to team sports was investigated. Monitoring the training process is a well-established practice in top-level sports to control the team's performance level and the fitness status of individual athletes to improve performance and avoid injuries (Halson, 2014). However, the training process is very complex and just looking at the conceptual frameworks main components results difficult to figure out the entire phenomenon. Instead, integrating all the analytical frameworks on the individual aspects of the training process is the key. In particular, regarding training loads to which athletes are exposed, it is important to consider both the physiological and psychological components of fatigue. Given this evidence, the aim of this thesis was to begin the validation process of two scales, the perceived mental exertion rating scale (M-RPE) and the perceived physical exertion sclae (P-RPE), to evaluate the perception of effort during training and competition for athletes. These scales were created using the modified RPE scale by Foster in 2001 and two specific questions to differentiate the physical from mental components of the athletes' perceived workloads. Five scientific studies have been run for the purpose of this doctoral project. A first study to evaluate the criterion validity of the two differentiated RPE scales was conduct. In addition, through a regression analysis of the responses to the questionnaires, it was possible to differentiate the different physical and mental contribution on the overall perception of effort experienced by athletes during training and competition. In study two the discriminating validity of the two scales of perception of mental effort and physical effort was investigated. Two teams were involved, one soccer Italian Serie D team and one rugby union Serie B team respectively. Two types of workouts, with both physical and technical aspects, from their respective training routines were evaluated in which a different physical and mental load was administered. In study three, four other team sport teams (two handball Italian Serie A and two volleyball Italian Serie C and Serie D) were monitored during two identical physical conditioning workouts to assess the reliability of the two scales. In study four the discriminant validity in laboratory condition was tested in a single visit, using a cross-counterbalanced design. Physical and cognitive load were modulated through different running speeds and with the presence of a free recall memory test. Finally, in a fifth study an example of practical application of the scales was descripted. In particular, the relationships between Psychological Training Loads and Mood states in élite Athletes was studied using linear mixed model. A new valid and reliable tool for assessing and differentiating perceived exertion is now available to athletes through this initial scientific validation process. To differentiate training loads into the different mental and physical components, can help in a better understanding of the mechanism of fatigue that athletes experience during training and competitions.

GENERAL INTRODUCTION

Conceptual Framework of Physical Training

Monitoring and control of training are established practices in high-level sports, both in individual and team sports. Today, many athletes, coaches and technical staff are taking an increasingly scientific approach to designing and monitoring training programs. Appropriate load monitoring helps in determining whether an athlete is adapting to a training program and in minimizing the risk of developing non-functional overreaching, illness, and even injury (Halson, 2014). In order to understand the effect of training load on athletes, a number of conceptual frameworks are available in the literature. The use of these tools is strongly recommended not only among practitioners, but for anyone who needs to consolidate a concept and use it concretely either in experimental practice for example in academia for scientific research, or in the field in planning and then implementing a given training protocol (D. Fletcher et al., 2012; David Fletcher & Hanton, 2003; Jeffries et al., 2021)je. A conceptual framework plays a central role in the entire scientific process. Its purpose is to include and synthesize evidence, to help practitioners understand phenomena, and it can be a useful tool to guide operations in practical field settings. Finally, it is a useful tool to inform future research on what are the most robust parts of a scientific theory and possibly to point out where there may be gaps that need to be filled with further investigation and scientific research. One of the most recent was presented by Jeffries and colleagues in 2021 (Jeffries et al., 2021). These authors propose an updated version of the classical frameworks of training process to facilitate the validation and interpretation of physical training measures.

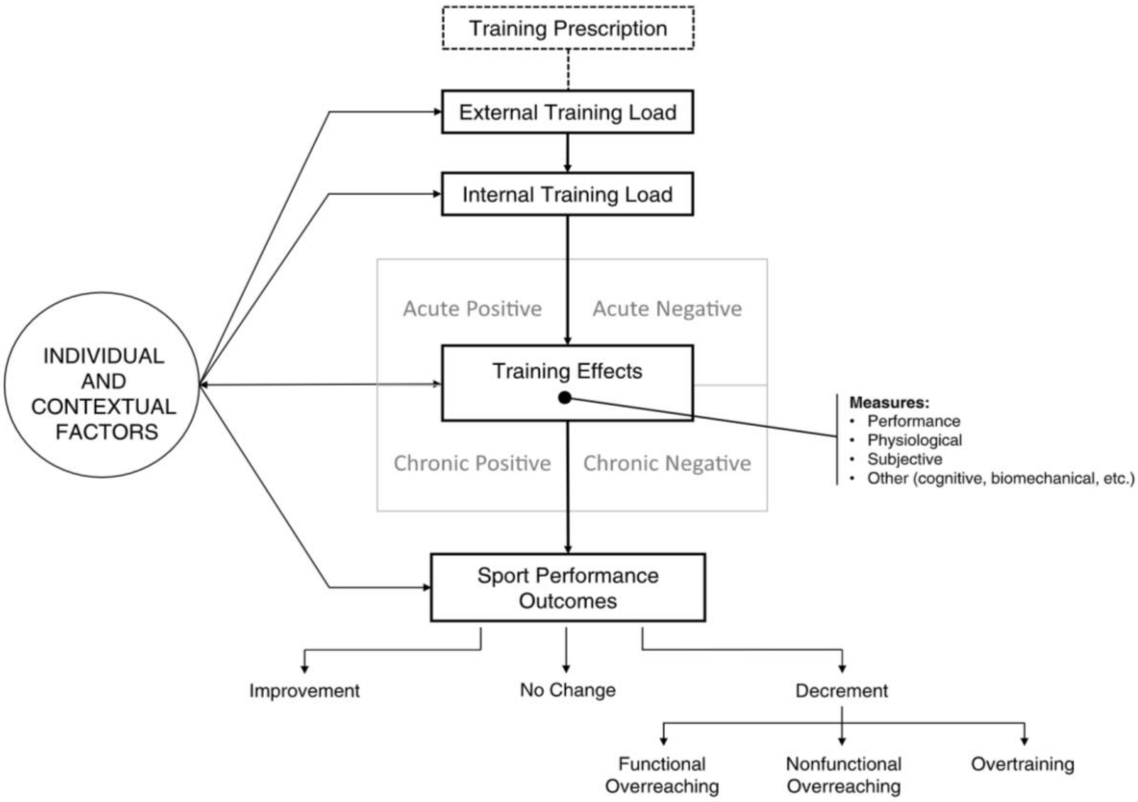


Figure 1. *Conceptual framework of the physical training from Jeffries and colleagues 2021;*

The framework was built through a process of qualitative analysis involving a synthesis of the literature. Banister fitness-fatigue training framework and PerPot models of training process have been integrated each other (Calvert et al., 1976; Morton et al., 1990; Perl, 2001). Furthermore, four construct were identified and explained by the authors: 1) introduction of a new measurable component: the “training effects”, a higher order construct resulting from the combined effect of the acute and the chronic, the positive and the negative responses to training; 2) explanation and examples of training effect measures such as performance, physiological, subjective and other measures like cognitive or biomechanical; 3) integration of the sport performance outcome continuum; 4) unidirectional and bidirectional linkages between individual and contextual factors and the other constructs.

The constructs that are the core elements of the framework are: training prescription, external and internal training load, the training effect, the sport performance outcomes, and the individual and contextual factors.

Exercise prescription covers both the single training session and the entire planning and periodization of training within and between training periods (Jeffries et al., 2021). The training prescription depends on performance models, contextual and individual factors, training effects (acute and chronic), previous training load experienced by the athletes, and coach knowledge and experience.

External load and internal load are the result of splitting the general concept of training load already used and widely recognized in the scientific literature of training methodology since the first appearances. In fact, the concept of training load has not always existed, but has only been introduced and defined since the early 2000s. Consequently, even in performance monitoring systems it has not always been possible to quantify training workloads using this construct and variable. Training load can be defined as the amount of training done and experienced by the athletes (Impellizzeri et al., 2019). Can be quantified using various measures or indicators of internal or external training load or aggregating and combining lower level constructs such as intensity and volume (Comyns & Flanagan, 2013). External training loads are what the athletes do in training and could be measured in e.g. by GPS or accelerometers. Internal Training loads refers to the internal responses to exercise and workout, and could be measured using psychological and physiological parameters (Impellizzeri et al., 2019, 2004; Jeffries et al., 2021).

Training effects can be described as the outcomes occurring after just a single training session, or after multiple training workout (Jeffries et al., 2021). If the adaptation to these workloads occurred for more than one training session but less than a week, or a micro cycle, can be considered an acute training effect. Conversely if the exposure to training stressors and consequently the recovery time takes more than a week, or more than an entire micro cycle, the resulting training effects can be considered chronic. Coaches' ability to manage both short and long-term adaptations throughout the competition periods of the season is an important key for improving athletes' performances. A further partitioning of the training effects proposed in this review, is the positive and negative type of adaptations. In other words, responses that directly impair or improve performance. For example, the category of negative training effects could include both the acute effects of a well-planned training program that involves a progressive increase in training loads and the effects of a training program that is not optimally planned and does not generate the desired long-term improvements in the athlete, even after an appropriate recovery period. The components included in the training framework are constructs for which there are no gold standards measure or variables. Fortunately, there are various measures employed to that purpose, including indirect measures reflecting the original construct or that depend directly by that. Authors presented some examples of training effect measures: performance measures, physiological measures, subjective measures, cognitive measures, biomechanical measures, and others. Each sport discipline, and sometimes even each coach, develop their own benchmark measures and variables in which to place their attention during the performance monitoring and the whole performance control process. There are not huge differences within related disciplines, but sometimes even small differences do not allow comparisons of measurements to make more in-depth analyses of phenomena.

Lastly, the sport performance outcomes are the results of the whole training process. Indeed, the balance between the positive and negative training effects, and the influence by contextual and individual factors (such as genetics, environment, psychological states, level of the opponent, etc.) cause the specific sport performance outcomes.

The first purpose to use the conceptual framework of training process suggested by the authors is for monitoring training process. This theoretical framework can represent a valid scientific reference and a guide for coaches and trainers through the process. Even if it does not represent an innovative tool, it is still a useful guide that allows practitioners not to miss important elements of the entire process or to get lost in one of these. A further possible use of the theoretical framework presented by Jeffries and colleagues is the identification of training tolerance for each athlete, which reflects the athlete's potential ability to cope with training stimuli. Finally, a further use of the theoretical framework presented by Jeffries and colleagues is represented by the estimate of the athlete's performance readiness. This review was made in order to attempt to provide a useful overarching framework for understanding the scientific literature regarding the training process. Additionally, this review could be adopted as guide to the development, implementation, and evaluation of a more comprehensive and transparent approach to athlete monitoring and a guide to the validation process of training related measures.

To get profitable results from the training monitoring process, it is necessary to implement a dynamic system based on solid scientific foundations. In this regard, the use of conceptual frameworks and quality scientific literature as reference is encouraged. However, an additional dynamic process is needed to further increase the predictive and control power of the monitoring system used. The knowledge of the physiological and psychological processes that occur in the athlete is constantly evolving in parallel with the scientific knowledge of reference. It is therefore necessary to continuously update variables and performance indicators and simplify databases by including valid and reliable variables in the first place.

Theoretical framework of Psychological Load

Recently, attention to stressors that are not directly training loads, such as psychological load, has increased. The International Olympic Committee's consensus statement defines psychological load or psychological distress as the consequence of athletes' exposure to psychogenic pain, internal conflicts, and external stress that affect performance (Garbutt 2017; Soligard et al., 2016). In an interesting two-part consensus statement, Soligard and Schwellnus clarified the importance of psychological, physiological, and epidemiological data integration in training load monitoring systems for high-level sports and athletes. In further, the authors highlight how psychological load, such as negative stress from personal and life events and daily hassles, can significantly increase the injury risk for athletes. (Schwellnus et al., 2016; Soligard et al., 2016). Mellalieu et al. in 2021 have proposed a new theoretical framework that identifies three main sources of psychological load in athletes: a) training and performance, b) organization, and c) personal (S. Mellalieu et al., 2021).

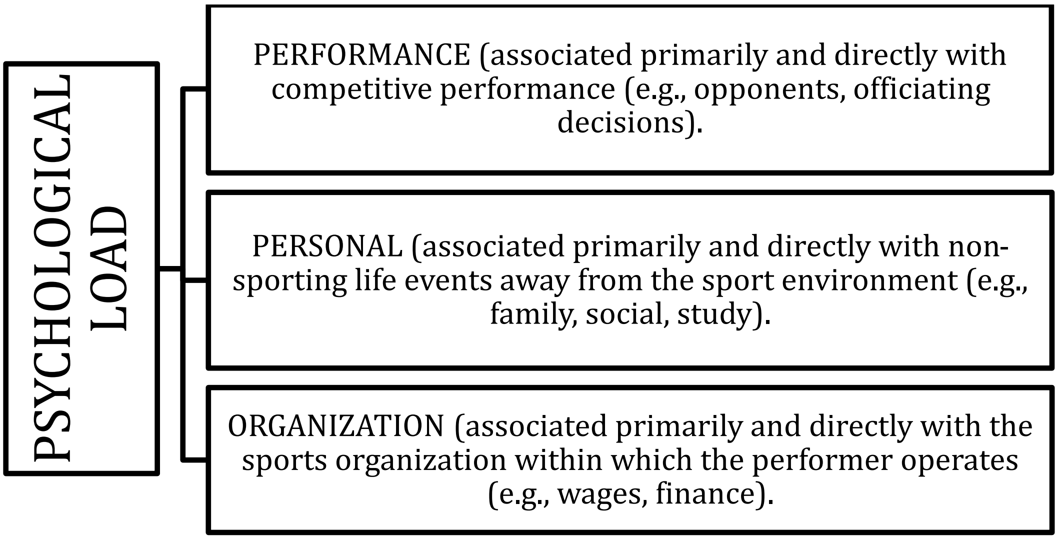


Figure 2. *Sources of psychological load experienced by athletes adapted from Mellalieu and colleagues 2021.*

The same author in collaboration with Fletcher and Hanton, in other interesting research developed a five dimension conceptual framework of organizational stressors in sports performers, identifying the main sources (Fletcher et al., 2012; David Fletcher & Hanton, 2003). Moreover, Mellalieu propose several practical implications for trainers to try to undertake proper psychological load assessment in sports. Detailed implications for practitioner are depicted in Figure 3.

▪ Monitor the athlete's (subjective) perception of the internal psychological load experienced, as opposed to attempt measurement of the objective external load placed upon the individual.
▪ Monitor the overall extent of the psychological load experienced, given the potential unique and vast array of sources (i. e., demands) contributing to an athlete's perception of their psychological load.
▪ Assess the psychological load that emanates from both participation in (sport load), and away from (life load), the sport.
▪ Take caution with the administration of instruments originally designed to measure psychological load in other occupations, owing to their potential lack of sport specificity and practical utility (e. g., time taken to complete).
▪ Consider both the psychological load experienced and the athlete's subsequent response (mental and physical) to the load to capture any potential dose-response relationship.
▪ Undertake monitoring of psychological load from both an acute and chronic perspective to measure the relationship with physical load, performance, and physical and mental health (injury and illness) over time.
▪ Acknowledge that the appraisal of the mental and physical psychological load encountered and the level of personal and social resources available will influence an athlete's ability to successfully cope.
▪ Consider groups of athletes who may be particularly 'at risk' of physical and mental injury and illness from increased psychological load. These may include athletes transitioning into (i. e., academy, junior elite) or out (i. e., retirement) of elite sport and those athletes who are long-term injured.

Figure 3. *Implication for practitioners seeking to assess psychological load. Extracted from the research by Mellalieu et al. of 2021.*

Although generic tools already exist to quantify different components of training load, these scales are generic and not training specific. Previous studies have proposed the use of scales such as differential-RPE (Barrett et al., 2018; Birdsey et al., 2022; Chatain et al., 2019; Gabbett et al., 2021; Jensen et al., 2006; Langvee, 2017; Lennon, 2020; Macpherson et al., 2019; McLaren et al., 2016, 2018; Murphy et al., 2014; Salter et al., 2021; Shariat et al., 2018; Weston et al., 2015), or the visual analog ones (Coyne et al., 2021; Impellizzeri & Maffiuletti, 2007; Thompson et al., 2019), or the rating scale of mental effort (Ghanbary Sartang et al., 2016; Widyanti et al., 2013), or the NASA Task Load Index (NASA-TLX) questionnaire as instruments to measure the different components of training loads (Filipas et al., 2021; Staiano et al., 2023, 2022). However, a very limited number of studies are valid and reliable (Coyne et al., 2022, 2018; Fuster et al., 2021). Nevertheless, there are no sport-specific validated questionnaires to measure psychological load or to differentiate between the physical and mental aspects of the training loads. Rather than creating a new one, as more widely used and understood, it might be more suitable to modify an already existed scale, such as the RPE scale, to assess athletes' psychological load.

Integrated Conceptual Framework

Frameworks in the literature help to understand the entire training process in detail and enable the development of tools for monitoring training loads appropriate to athletes and their level of competition, it is also true that these are not always complete and exhaustive. for example, the framework of Jeffries and colleagues does not identify the psychological load athletes are subjected to during their sports experience. No one of the aspects of the psychological load defined by Mellalieu and colleagues is detailed in Jeffries' framework. It is impossible to place the psychological load construct at a specific point in the training process framework proposed by Jeffries and colleagues, but it is possible to place its sources in different points of the conceptual scheme. In particular, the source identified as performance can be included as an internal load or as an individual factor that influences the entire training process. During both competition and training, the stress generated can be interpreted as a response to performance or as a psychobiological condition that affects the athlete consequently to the exposure to the stress that competition and training sessions generates. The sources that generate psychological load in the athlete identified as organizational and personal influence individual and contextual factors, which in turn influence the entire training process.

Literature Review

The following chapters provide a non-systematic review of the literature on monitoring training loads in team sports and about the use of differentiating training loads measures to assess different components of the loads which athletes are exposed throughout the training process. In this brief updated narrative review of the relevant literature, we focused on the various types of stress generated in the athlete, not only on physical and physiological loads, but also on all the stress variables representing mental and psychological loads. An attempt was made to identify where within the reference literature the topic of external sources of stress to which the athlete is exposed throughout his or her career was undertaken differently respect to the traditional approach which consist in measuring the physical components of the external and the internal training loads.

Monitoring training and performance in athletes

Training monitoring has been a habitual and well-established practice in top-level sport for long enough to have produced a large and detailed scientific literature. It is an essential tool for determining the effects of athletes' training programs and quantifying physiological and psychological responses in terms of quantity and duration (Halson, 2014). The monitoring of the training process is as complex as the performance model of the sport to which it is applied. It consists of the repeated measurement of all variables and performance indicators that allow coaches and practitioners to detect changes in the athlete's psycho-physiological condition and to control the parameters that in literature resulted related to the athletes' ability to best perform in training and competition. Many coaches and physical trainers with their respective staff, are taking an increasingly scientific approach to both planning and monitoring training process. The need to individualize workloads and the continuous demand for differentiation of training prescriptions allowed a rapid evolution of methods and supporting tool for training monitoring. Furthermore, the physical, physiological, and psychological variables that allow us to observe the indirect effect of training on the body of the athlete and the whole team are subject to continuous investigation.

Interindividual differences in recovery, in exercise capacity, and general athletes' stress tolerance may explain the difference sport performance outcomes of the athletes under identical training conditions and experience. A key point in training monitoring field is to evaluate athletes individually. Overtraining studies have demonstrated that psychological indicators are more sensitive and consistent than physiological indicators (Meeusen, 2008; Meeusen et al., 2013; Proost et al., 2022). Common indices used in field sports within session include the Profile of Mood States (Rohlfs et al., 2008), Borg RPE (Shariat et al., 2018), session RPE (Impellizzeri et al., 2004), the Recovery-Stress Questionnaire for Athletes (Kellmann et al., 2018), and the Training Distress Questionnaire for athletes (Main & Grove, 2009). Adopting appropriate loads monitoring methodology is a key point and depends on the practitioner prospective on the collected data utilization. Although there are many studies on these measurement tools, none is considered exhaustive for measuring the psychological stressors athletes are exposed. Together with the questionnaires, which with different time frames allow the monitoring part of the psychological loads, some internal load measures are considered for a more global and holistic approach. The internal response of athletes is affected by training loads and by extra-training loads. Measuring the whole internal training loads responses experienced by athletes, also include the psychological loads. Using modeling approach and comparing training effect between and within athletes in different time periods is a useful and established practice in élite sport.

Psychological load and the use of differential RPE

In professional high level sports, one of the most widely used ways to measure internal load is the session RPE (Rating of Perceived Exertion) method, introduced by Foster and colleagues in 2001 (Foster et al., 2001). This method was adopted in all sport levels, because of its validity and feasibility in terms of practicality and low cost, as well as the ease for athletes to understand it.

In team sports, this method was introduced by Foster and colleagues in 2001. Specifically, in soccer it was introduced by Impellizzeri et al. in 2004, who validated its use by comparing it with other classical measures of internal load that were primarily used at the time. At the end of the last century, this methodology was developed and gained momentum due to the successes of Borg and colleagues' research on perception of effort.

More recently, McLaren and colleagues have applied the concept of differentiated RPE originally proposed by Borg (Borg, 1990, 2004) to the evaluation of the internal training load. These authors proposed four differentiated RPE scales: one for dyspnea and breathlessness exertion and one for cognitive/technical demand with the respective names, one for lower limbs called leg muscle exertion scale, and one for upper limbs called upper-body muscle exertion scale (Gabbett et al., 2021; Hendricks et al., 2019; McLaren et al., 2018, 2017). Although very interesting, while Borg's initially proposed differentiation has a rationale, Mclaren's recent differentiation has some objectionable aspects. In particular, regarding the cognitive/tactical effort scale, tactical training and physical conditioning workouts also have an amount of cognitive load. For example, the cognitive ability to control the inhibitory response is necessary for athletes to perform unpleasant workouts. In addition, mental aspects involving psychological load are generated and mediated by emotion and motivation and other cognitive aspects. Finally, the term cognitive is a technical term used in general psychology that athletes and lay people can easily misinterpret. Controlling psychological load in sports requires considering all psychologically mediated aspects of workload and quantifying them correctly.

Aims of the research

Given this evidence, the purpose of this multiple study was to investigate the feasibility, reliability, discriminant, and criterion validity of two RPE-based scales that separate the psychological load of a training session from the physical one, the perceived mental exertion rating scale (M-RPE) and the perceived physical exertion sclae (P-RPE). To answer the research questions, we have run five different studies. To assess the criterion validity, we compared the physical and the mental effort items of a validated and widely used questionnaire with the outcome of the differential RPE scales, rated by a heterogeneous group of trained people and athletes after some workout of their training routine. Therefore, using the stepwise method of linear regression analysis we assess the contribution of the physical and the mental effort to the overall rated effort perceived by the participants of present research. Moreover, scale's validity to discriminate different training types was tested collecting a 3-week multiple training sessions database with a Rugby Union National Level team, and a 4-week database with a Soccer National Levels team. Hence it was possible to assess the agreement for both scale responses, each within and between subjects. Finally, we tested the reliability of the scales using the test-retest method, or rather asking 2 handball and 2 volleyball National Levels teams to repeat twice the same training prescription. By using these scales, an attempt was made to quantify and to differentiate the acute psycho-physiological response to the training stressors experienced by athletes.

In general, the purpose of the series of studies was to begin the validation process of two new RPE-based scales to differentiate the physical and the mental component of the internal training load. Finally, the ecological validity of the instrument was investigated. A pilot study tested the use of scales in monitoring the training loads of some professional and semiprofessional team sports teams, differentiating effort experienced by athletes during sport practices.

GENERAL METHODS

Creation and development of the scales

To discriminate the two main components of psychological load in performance (training and competitions), two perceived exertion rating scales were created ad hoc: the perceived mental exertion rating scale (M-RPE) and the perceived physical exertion rating scale (P-RPE). As scales to be displayed, it was decided to choose the easiest for athletes to understand, as well as the most popular and familiar for athletes. The CR10 scale adapted from Foster was used in the present research as effort rating scales (Foster et al., 2001), and is depicted in Figure 4 and in Appendix 1.

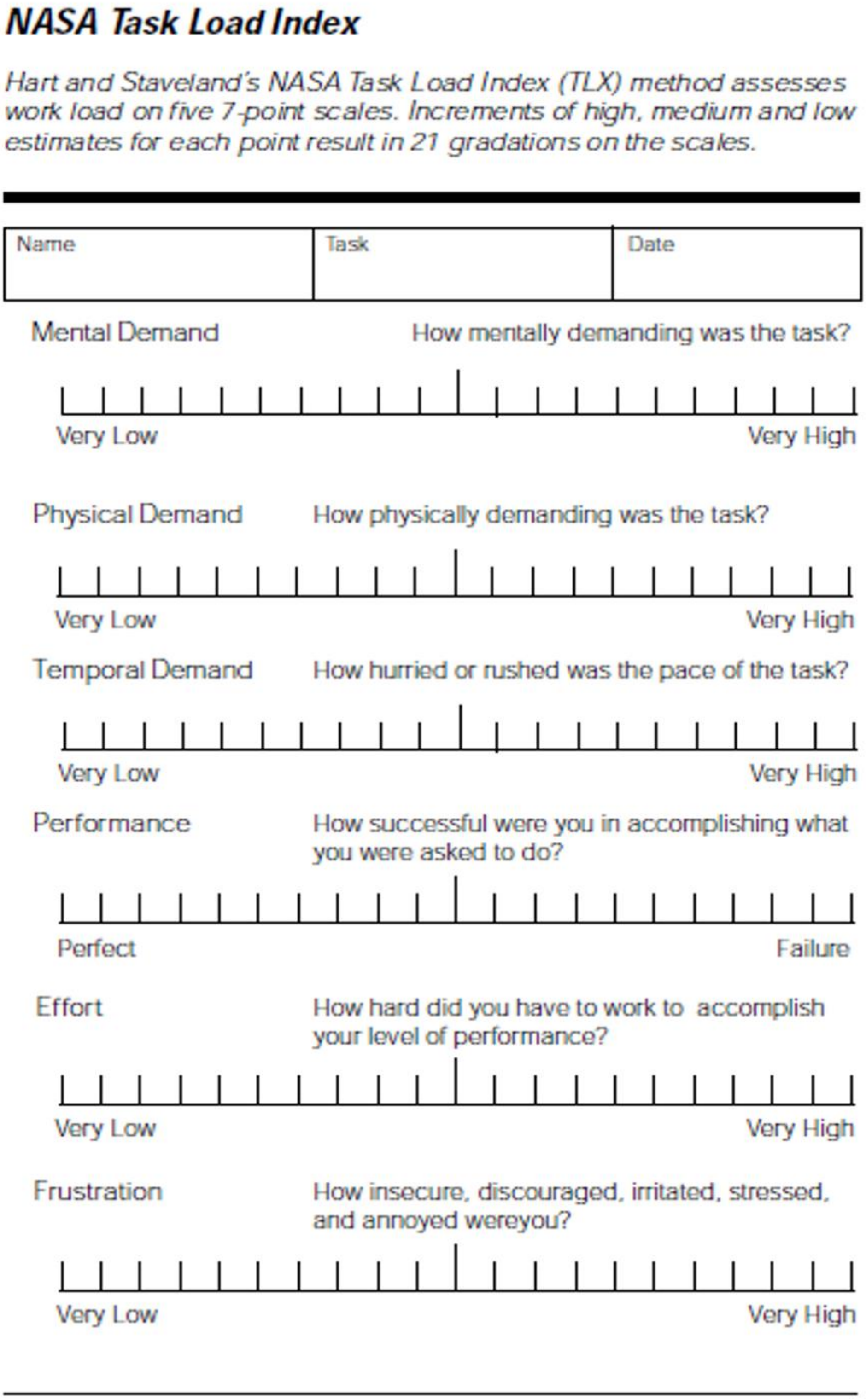
RATING	DESCRIPTOR
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	.
7	Very Hard
8	.
9	.
10	Maximal

Figure 4. *Reproduction of the modified scale of rating of perceived exertion (RPE) used by Foster and colleagues in 2001.*

This scale has already been used in several previous studies (Coutts et al., 2009; Haddad et al., 2017; Impellizzeri et al., 2004). The questions paired with the rating scales were first created in English and then double-translated into Italian to be used with a sample of native Italian-speaking athletes. The questions were created by merging the differential scales previously suggested by Borg and including terms frequently used in the scientific literature to describe cognitive demand during exercise, for physical and mental demand, respectively. Instructions were initially drafted by the authors and then discussed with experts in psychology and training load monitoring until a final version and a consensus was reached. For the P-RPE, participants were asked to rate the muscular and/or respiratory effort required by the training session. For the first time, respiratory and muscular effort were grouped together under one item. For the M-RPE, participants rated how demanding the training session was in terms of attention, concentration, learning, memorization, emotion, and motivation required. Finally, the scales were translated cross-culturally from English to Italian, and then back to English to check that there were no differences between the two English versions. Then the validity and reliability of the scales of perceived physical exertion and mental exertion were tested in the present research.

Choice of criterion measure

Usually for this kind of statistical validation, the measure universally believed to be the gold standard is used. Unfortunately, in this circumstance no official reference measure exist. A literature review of applied studies was carried out by Anacleto Filho and colleagues in 2024 to identify which measure is commonly used to assess mental workload (Filho et al., 2024). One of the main findings of the research shows that subjective methods are the most widely used in all industries, with a predominance of use of the NASA-TLX questionnaire over the others. An example of the questionnaire is reported in Figure 5, while the version used in the present research is shown in Appendix 4 and 5.



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Figure 5. *Reproduction of the NASA-TLX questionnaire. Available from official NASA website. Link: https://humansystems.arc.nasa.gov/groups/tlx/downloads/TLXScale.pdf*

For this reason the NASA-TLX questionnaire adapted to training was adopted as a criterion measure because the proper validation process has long been published (Hart, 2006; Hart & Staveland, 1988) and is one of the most widely used in the scientific sports literature (García-Calvo et al., 2021; Mullen et al., 2021; Ponce-Bordón et al., 2022; Soylu et al., 2022; Van Cutsem et al., 2016). In particular, the two items from the Italian version of the NASA-TLX questionnaire regarding physical (P-NASA) and mental (M-NASA) demand were also used in the present research (Said et al., 2020). All other measures of physical and mental exertion found in the literature are less widely used and sometimes even lack adequate studies to support their validity, compared with the NASA-TLX questionnaire adapted to training.

Despite its wide use and proven validity, administering the NASA-TLX questionnaire to athletes, they often highlights some of the following problematic: is a different scale from those used daily by athletes in training monitoring; athletes do not like the 1-20 scale; finally, athletes dislikes verbal anchors exclusively associated at the top and bottom of the scale, preferring the scales in which verbal anchors follow the entire numerical gradation.

Given this evidence, ten points scales seem to be potentially preferable and more optimal to represent an athlete-friendly monitoring tool. Moreover, being more comprehensible, it should consequently also increase the reliability of the instrument and the repeatability of the measurement, decreasing the measurement bias.

General procedures

After giving informed consent, all the participants filled in a short questionnaire and five unidimensional scales 30 minutes after one of their regular physical training sessions. The questionnaire consisted of some questions about personal details, practiced sport, training experience, and the content of the training just performed. After completing the general part of the questionnaire, participants rated how hard the training session was overall (O-RPE) using the RPE CR10 scale modified by Foster (Foster et al., 2001). Afterwards, participants rated their training according to the following four scales presented in random order: the physical demands and the mental demands subscales of the NASA-TLX questionnaire, the P-RPE and the M-RPE differentiated RPE scales. These procedures were strictly maintained both with those who were monitored only for a single training session and with who were monitored for two or more sessions. When athletes were involved for more than one training session, only the part of the questionnaires containing the mental exertion, the physical exertion and the overall exertion rating scales were administered.

The head coach of each team was asked to keep a diary of the training sessions conducted in which he detailed the contents of each of the training sessions executed during the period of this study occurred. When the study was finished, as the last step of data collection, the coaches were asked to provide a report with the content of the workouts. Finally, all the training session were classified by type by according with the classification previously proposed by Malone and colleagues for Soccer, by Duarte and colleagues for Volleyball, and by McLaren for Rugby Union (Duarte et al., 2019; Malone et al., 5 2015; McLaren et al., 2017). These last were adopted to classify all the other training session executed by unspecified or athletes that cannot be included in the previous groups of team sport athletes.

The Ethics Committee of the University of Bologna approved all procedures used in this research (N° Protocol: 0058119). In addition, each athlete has completed an informed consent form, which can be found in the appendix. Throughout the duration of the experiments, the true purpose of the research was masked, and the athletes were told that the purpose was to test the congruence of the scales with the type of training performed.

Study 1 - Criterion validity (Correlation between subjects)

INTRODUCTION

As a first step in the validation process of the differential RPE scales, a correlation study with a gold standard is recommended. Unfortunately, a gold standard for this type of measure is missing. The measure most used by the scientific community for the estimation of that specific phenomenon becomes in fact the reference measure to be used in scientific research or to be chosen as a criterion measure to validate new types of measurements of the same phenomenon. The scientific literature in this field is quite limited and some reviews have been made about the subject. A literature review of applied studies was carried out in 2024 by Filho and colleagues to identify which measure is used to assess mental workload (Filho et al., 2024). One of the most used questionnaires is the NASA-TLX.

The main purpose of this study was to assess the criterion validity of the two new differential RPE scales. We compared the physical and the mental exertion items of the NASA-TLX questionnaire with the results of the differential RPE scales, rated by trained individuals and athletes after a workout of their routine. The number of athletes was chosen in accordance with the guidelines of Arleene Fink and described in the book: "The Survey Handbook."

Athletes were chosen by including a number of athletes similar to that used in previous similar research, such as that of Jeffries and colleagues in 2023, both in terms of the validity study and the reliability study (Fink, 2003; Jeffries et al., 2023).

A secondary aim of this study was to assess the contribution of physical and mental exertion to the overall perceived exertion during exercise. We hypothesize that the new scales have a very high and significant correlation with the criterion measure. Furthermore, we hypothesize that the contribution of physical effort is greater than the contribution of mental effort to the amount of overall effort perceived by athletes tested in this research.

METHODS

Participants

Two hundred and two athletes were recruited and voluntarily took part in the present research. A total of 130 males and 72 females provided written informed consent (Appendix n°) and were included in the final sample of the study. They were all free from injury in the twelve months prior to the study took place. Athletes filling a self-report questionnaire about age, height, weight, and training history. According to the criteria of the performance level classification framework proposed by McKay and colleagues in 2022 (McKay et al., 2022), the participants at the present study were all Trained to International level athletes. Moreover, each of the participants has been personally instructed by one of the researchers on the right procedures to fill out the questionnaires. All the participants were used to working out at least three times per week in the past 3 months from the beginning of the present research. In agreement with the coaches and athletic directors, no training program was altered or modified during the entire duration of the study. All the characteristics of participants, divided per sample groups, are described below in Table 1.

Sport	N (Gender)	Age [year]	Stature [cm]	Weight [Kg]	Level	Study duration
Track Field	9 (8m, 1f)	28.1 ± 7.1	172.6 ± 10.0	64.9 ± 8.7	1 International 5 National 3 Trained	Single training session
Cycling	18m	24.4 ± 2.8	173.2 ± 5.7	62.9 ± 4.5	International	
Fitness	21 (14m, 7f)	26.2 ± 6.9	171.8 ± 7.6	70.3 ± 7.6	Trained	
Weightlifting	5 (4m, 1f)	24.4 ± 3.4	167.8 ± 3.6	66.6 ± 8.7	3 National 2 Trained	
Volley (juniors)	51 (25f, 26m)	17.6 ± 1.2	182.9 ± 10.1	73.5 ± 10.0	25 Under 18, 26 Under 19, National	
Handball	30 (16m, 14f)	23.0 ± 3.4	176.8 ± 7.5	72.0 ± 6.5	National Serie A1	Double training session
Volley	24f	21.8 ± 2.2	168.8 ± 6.7	59.7 ± 4.3	12 National (Serie C), 12 National (Serie D)	
Rugby Union	25m	27.7 ± 4.8	180.5 ± 5.6	94.6 ± 15.6	National (Serie B)	3 weeks
Soccer	19m	23.3 ± 3.7	183.4 ± 6.9	78.0 ± 8.1	National (Serie D)	4 weeks
Total	202 (130m, 72f)	24.1 ± 3.9	175.3 ± 4.9	71.4 ± 6.0	26 Trained, 157 National, 19 International	-

Table 1. *Details of the participants at the present research are reported, divided per group.*

Procedures

After giving informed consent, all participants completed the questionnaires 30 minutes after one of their regular physical training sessions. After completing the general part of the questionnaire, participants rated the overall difficulty of the training session (O-RPE), then participants rated their training with the physical and mental demand scales of the NASA-TLX questionnaire and with the differentiated rating scales for physical exertion and mental exertion, in random order.

Statistical Analysis

Nonparametric statistical techniques should be preferred to analyze the data obtained in the present study because the outcomes of the rating scales used are discrete and not continuous variables. However, both scales have more than 7 possible responses, so it is allowed to prefer parametric statistics to analyze the relationships between the responses to the different scales by the athletes (Jeffries et al., 2023). Specifically, Pearson's correlation was performed between subjects to establish the criterion validity of the new scales with respect to the corresponding items of the NASA-TLX questionnaire (criterion measure or gold standard). According to Hopkins et al., correlation coefficients of 0.1, 0.3, 0.5, 0.7, and 0.9 were interpreted as small, moderate, large, very large, and extremely large relationships, respectively (Hopkins, 2000).

Effect sizes were interpreted as small, medium or large if they were < 0.2, between 0.2 and 0.5, and above 0.5 respectively according to Cohen guidelines (Cohen, 2013). Moreover, a stepwise linear regression analysis was conducted to quantify how much mental rather than physical effort contributed to the overall RPE. The overall perception of effort was set as a dependent variable, while the mental-RPE and the physical-RPE represented the two covariate variables.

Significance was set at an alpha level of $p \leq 0.05$ for all the analysis. All data are reported as mean ± SD. All data were processed using Excel spreadsheets, JASP software (Version 0.17.1), and RStudio software (R Core Team 2022).

RESULTS

The M-RPE scores were highly correlated with the M-NASA scores (r=0.804, p<0.001, ES 1.111) whilst the P-RPE scores were highly correlated with the P-NASA scores (r=0.845, p<0.001, ES 1.238). The overall RPE also showed a very high correlation with the M-RPE, r=0.774, p <.001 and ES 1.029, and with the P-RPE, r=0.838, p <.001 and ES 1.214. All results are reported in Table 2 and depicted in Figure 6 and Figure 7. In both the physical exertion item and the mental exertion item, the correlations turn out to be very large according to the interpretation of Hopkins and colleagues (W. G. Hopkins, 2000). Furthermore, according to Cohen's guidelines on Effect size interpretation, all comparisons are found to have a large effect (Cohen, 2013).

Pearson Correlations

Variable		M-RPE		P-RPE		M-NASA		P-NASA		O-RPE
1. M-RPE	n	—								
	Pearson's r	—								
	p-value	—								
	Upper 95% CI	—								
	Lower 95% CI	—								
	Effect size (Fisher's z)	—								
	SE Effect size	—								
2. P-RPE	n	202		—						
	Pearson's r	0.724	***	—						
	p-value	< .001		—						
	Upper 95% CI	0.784		—						
	Lower 95% CI	0.651		—						
	Effect size (Fisher's z)	0.916		—						
	SE Effect size	0.071		—						
3. M-NASA	n	202		202		—				
	Pearson's r	0.804	***	0.605	***	—				
	p-value	< .001		< .001		—				
	Upper 95% CI	0.848		0.686		—				
	Lower 95% CI	0.750		0.509		—				
	Effect size (Fisher's z)	1.111		0.701		—				
	SE Effect size	0.071		0.071		—				
4. P-NASA	n	202		202		202		—		
	Pearson's r	0.660	***	0.845	***	0.721	***	—		
	p-value	< .001		< .001		< .001		—		
	Upper 95% CI	0.732		0.880		0.781		—		
	Lower 95% CI	0.575		0.800		0.647		—		
	Effect size (Fisher's z)	0.793		1.238		0.909		—		
	SE Effect size	0.071		0.071		0.071		—		
5. O-RPE	n	202		202		202		202		—
	Pearson's r	0.774	***	0.838	***	0.665	***	0.783	***	—
	p-value	< .001		< .001		< .001		< .001		—
	Upper 95% CI	0.824		0.875		0.735		0.831		—
	Lower 95% CI	0.712		0.791		0.580		0.723		—
	Effect size (Fisher's z)	1.029		1.214		0.801		1.053		—
	SE Effect size	0.071		0.071		0.071		0.071		—

* p < .05, ** p < .01, *** p < .001

Table 2. *Pearson's correlation between P-RPE and M-RPE, with M-NASA and P-NASA and with the O-RPE scores are detailed. Upper and Lower 95% Confidence Interval, and Effect sizes (Fisher's z and Cohen's d) are reported. * p<.05, ** p<.01, *** p<.001.*

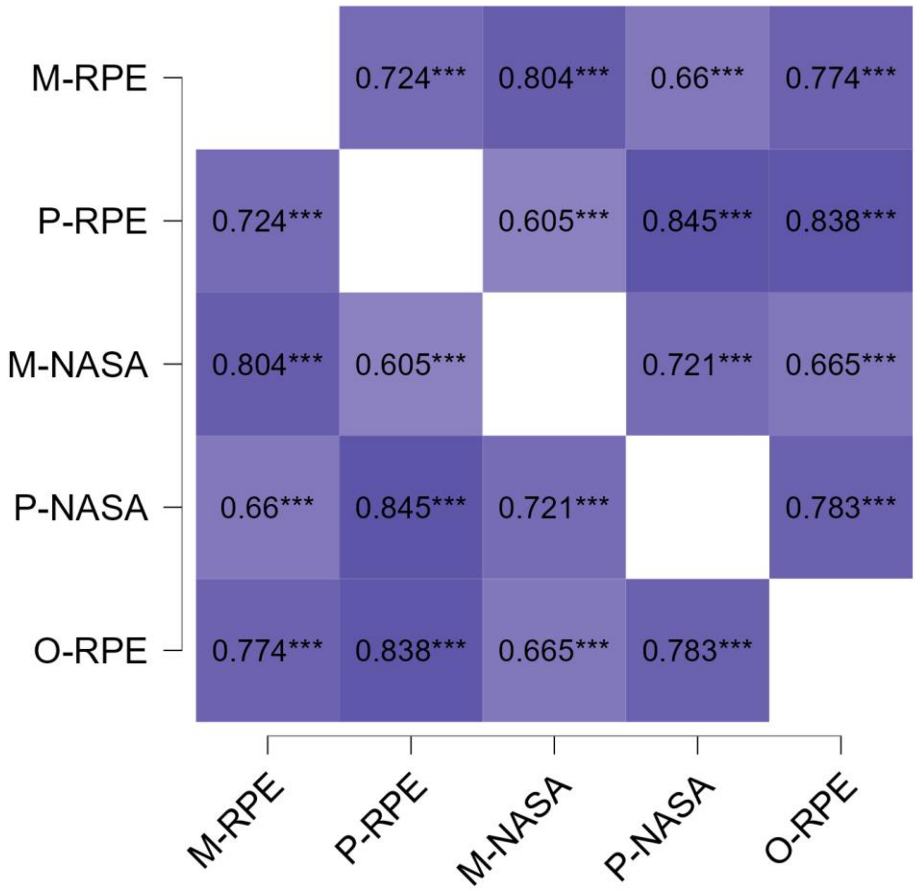


Figure 6. *Heatmap representing the correlation between: M-NASA, P-NASA, M-RPE, P-RPE and O-RPE; Within each square the Pearson correlation value was reported, with * symbol if the comparison resulted significant. The color intensity of the square is related to the strength of the estimated relationship.*

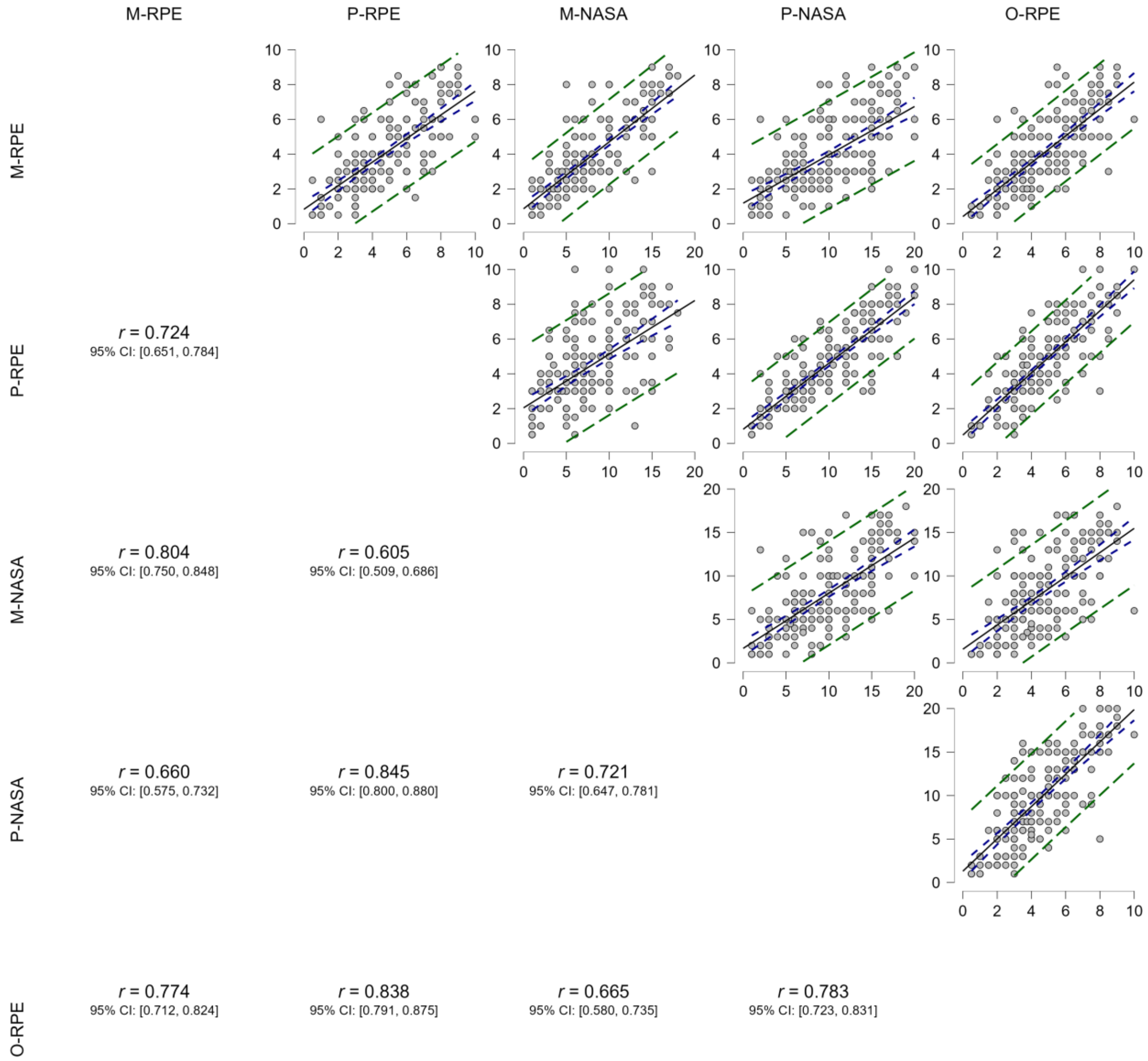


Figure 7. *Scatter Plots representing the correlation between: a) M-NASA and M-RPE, b) O-RPE and M-RPE, c) P-NASA and P-RPE, d) O-RPE and P-RPE, e) the residuals of M-RPE and residuals of O-RPE, and f) the residuals of P-RPE and residuals of O-RPE. In all plots are depicted trends solid lines, dotted confidence intervals curvy lines and dotted prediction intervals straight lines.*

A multiple linear regression was calculated with a stepwise method to assess the impact of M-RPE and P-RPE on the O-RPE. A significant regression equation was found ($F(2,199) = 316.207$ and $p<.001$), with an R^2 of 0.76. Participants' predicted O-RPE is equal to 0.654 + 0.548 * P-RPE + 0.351 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). Participants' O-RPE was caused by 60% of the P-RPE and by 36% of the M-RPE. The following tables show the summary of the linear regression model (Table 3), the table of estimated Coefficients per each of the three models estimated (Table 4), the part and the partial correlation (Table 5) and the collinearity diagnosis per each of the model estimated (Table 6). While the coefficients of the regression equation are obtained from the first tables, the last tables can be used to check the relationships and partial relationships among the variables involved in the present analysis and through collinearity analysis whether it is appropriate to perform modifications to the regression analysis methodology adopted to not decrease the power of the inferences. In particular, none of the parameters took into consideration can determine further analysis (VIF<2.101, R^2=0.702-0.761). There are also reported the partial regression plot (Figure 7) and the marginal effect plot (Figure 8), that depicted the relationship between the residuals of the dependent variable and both the independent variables (a and b). In these last plots the confidence intervals and the predicted value lines are also depicted. Finally, the residuals versus the dependent (Figure 9), versus the covariate (Figure 10) and versus the predicted variables (Figure 11) are depicted, with the standardized residuals added in secondary y-axis.

Model Summary - O-RPE

Model	R	R^2	Adjusted R^2	RMSE	R^2 Change	F Change	df1	df2	p
1	0.000	0.000	0.000	2.078	0.000		0	201	
2	0.838	0.702	0.701	1.137	0.702	471.152	1	200	< .001
3	0.872	0.761	0.758	1.022	0.059	48.757	1	199	< .001

Table 3. Model summary of the regression analysis with the Overall-RPE as dependent variables. The coefficient of correlation (R), his squared (R^2), the adjuster R^2, the Root Mean Squared Error, the change of F and the p value are reported.

Coefficients

							95% CI		Collinearity Statistics	
Model		**Unstandardized**	**Standard Error**	**Standardized**	**t**	**p**	**Lower**	**Upper**	**Tolerance**	**VIF**
1	(Intercept)	4.420	0.146		30.227	< .001	4.131	4.708		
2	(Intercept)	0.945	0.179		5.278	< .001	0.592	1.298		
	P-RPE	0.786	0.036	0.838	21.706	< .001	0.715	0.857	1.000	1.000
3	(Intercept)	0.654	0.166		3.935	< .001	0.326	0.981		
	P-RPE	0.548	0.047	0.584	11.613	< .001	0.455	0.641	0.476	2.101
	M-RPE	0.351	0.050	0.351	6.983	< .001	0.252	0.451	0.476	2.101

Table 4. Table of estimated coefficient of the linear regression analysis. Next to each model are shown the standardized and the unstandardized error, the t and the p value, the confidence intervals, and the collinearity statistical values.

Part And Partial Correlations

Model		Partial	Part
2	P-RPE	0.838	0.838
3	P-RPE	0.636	0.403
	M-RPE	0.444	0.242

Note. The intercept model is omitted, as no meaningful information can be shown.

Table 5. Part and partial correlation per each estimated model.

Collinearity Diagnostics

				Variance Proportions		
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Intercept)**	**P-RPE**	**M-RPE**
2	1	1.894	1.000	0.053	0.053	
	2	0.106	4.237	0.947	0.947	
3	1	2.810	1.000	0.022	0.011	0.013
	2	0.132	4.619	0.947	0.072	0.192
	3	0.058	6.948	0.032	0.916	0.795

Note. The intercept model is omitted, as no meaningful information can be shown.

Table 6. Collinearity diagnostics based on collinearity statistics.

Partial Regression Plots

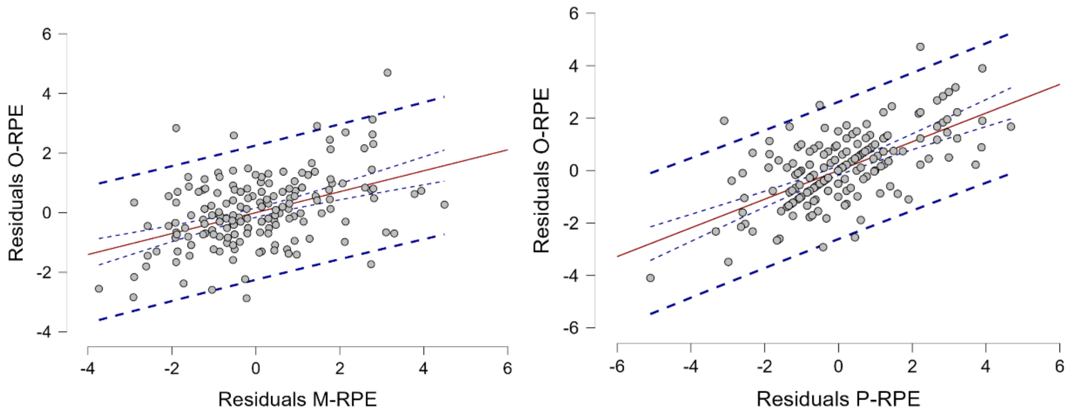


Figure 7. *Partial regression plot between the residuals of the dependent variables O-RPE and the residuals of the two independent variables M-RPE on the left and P-RPE on the right. In both plot solid red lines represent the trend lines, curved dotted lines represents the confident intervals and the blue thicker dotted lines are the predicted values.*

Marginal Effects Plots

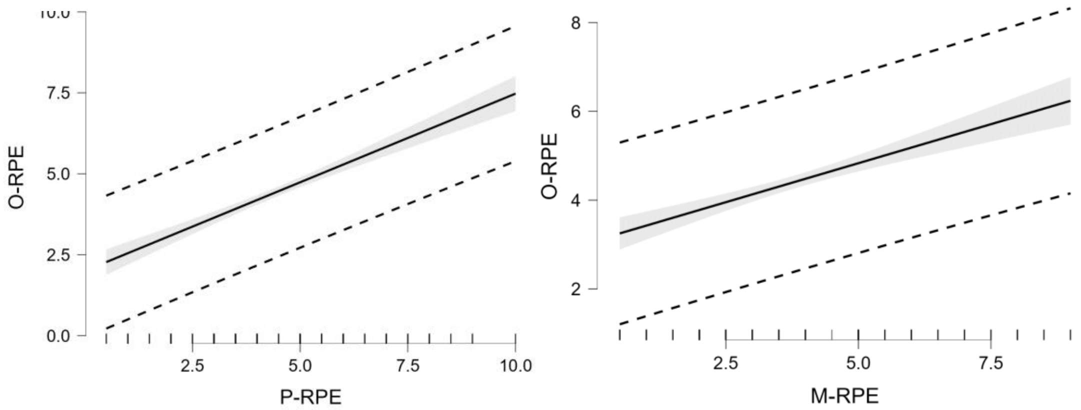


Figure 8. *Marginal effects plot between the residuals of the dependent variables O-RPE and the residuals of the two independent variables M-RPE on the right and P-RPE on the left. In both plot solid black lines represent the trend lines, grey areas represent the confident intervals, and the dotted lines are the predicted values.*

Residuals vs. Dependent and vs Predicted

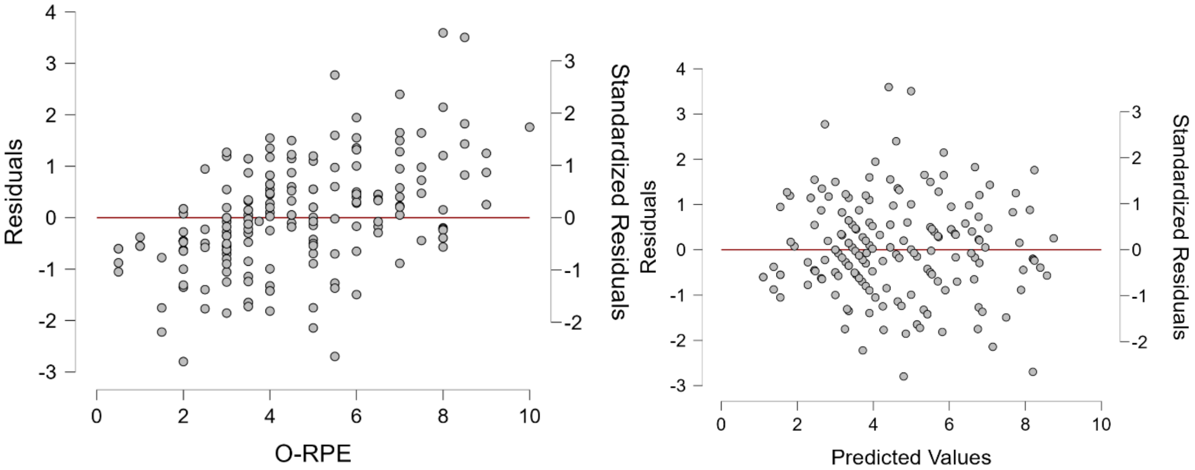


Figure 9 and 10. *Residuals and Standardized residuals of the dependent variables O-RPE and the predicted variables are depicted.*

Residuals vs. Covariates

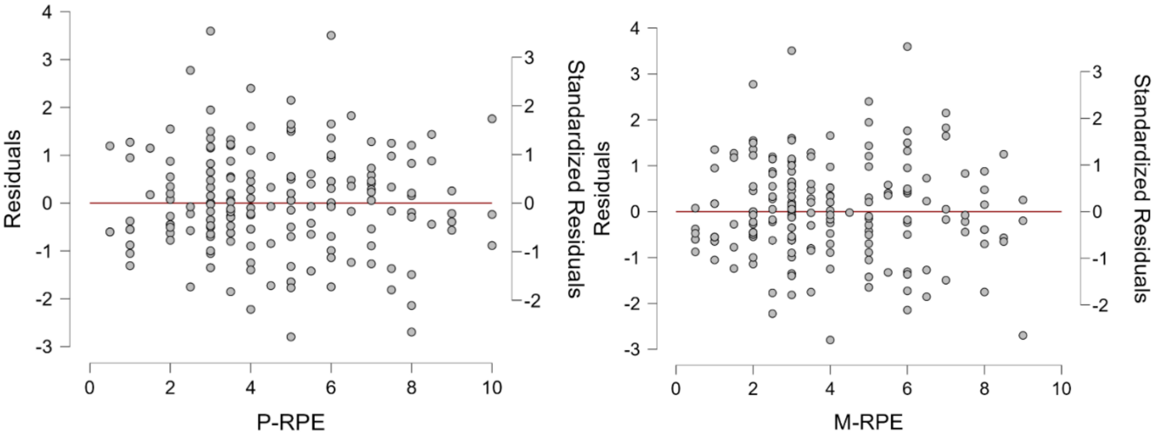


Figure 11. *Residuals and Standardized residuals of the two covariates variables P-RPE on the left and P-RPE on the right are depicted.*

DISCUSSION

These instruments showed good agreement in measuring the physical and mental components of effort experienced in training by athletes. Correlation analysis indicates that the new questionnaires are valid and could represent a valid alternative to the criterion measurement. In addition, the results of the regression analysis indicate that the O-RPE experienced during training appears to be mediated by both physical and mental effort, justifying the use of two different scales, for the mental and the physical perceived efforts. The P-RPE is similar to the O-RPE, but it is not the same, so you also need the M-RPE because you don't measure all the perceived load only with the P-RPE scale. Given the results of the present study, the use of differentiated scales for perceived exertion with high-level athletes by practitioners is strongly encouraged. Further investigations are needed on the validity and the reliability of these new differential RPE scales in order to incorporate them within the training monitoring systems used by coaches and physical trainers in high-level sports.

Study 2 - Discriminant Ecological Validity and Within Subjects Correlation

INTRODUCTION

To achieve the purpose of this PhD thesis, after an initial study to investigate the criterion validity of the differentiated scales, a second study to assess the discriminant validity of the scales was designed. A 3-week and a 4-week training monitoring study was conducted to evaluate the ecological validity of the scales of perceived physical and mental effort to discriminate between different types of training sessions. Two National level teams were involved in the present research, a Rugby Union and a Soccer teams, respectively. Both teams were monitored with the two new differential RPE scales for several weeks during their respective training routines. Training diary was recorded by the coaches throughout the study. By knowing the types of training performed and how the respective physical and mental loads were modulated, it was possible to study the differences detected by the new differential RPE scales in the various types of training experienced by the athletes.

The main purpose of this part of the research was to test if the two differential RPE scales can detect different mental load and physical load athletes experience in training. A secondary aim of the study was to assess the correlation of the two differential RPE scales with the criterion measure (NASA-TLX questionnaire) tacking into account the intra individuals' variability in answering to the questionnaires. Within-subject correlation analysis was added per each of the scales to the between-subject correlations of study 1.

METHODS

Regarding the field part of the study, ethical approval and informed consent were not required because the data collection did not consist in any kind of manipulation of the athletes' workloads and was part of the training monitoring routine of the athletes involved (Winter & Maughan, 2009).

Participants

Forty-four Rugby Union (n= 25) and Soccer (n=19) athletes were asked to be monitored for 3 and 4 weeks respectively. Rugby players competed in National Serie B championship during 2022/2023 season and were 27.7 ± 4.8 years old, 180.5 ± 5.6 cm height and 94.6 ± 15.6 weight. Soccer players competed in National Serie D championship during 2022/2023 season and were 23.3 ± 3.7 years old, 183.4 ± 6.9 cm height and 78.0 ± 8.1 weight. All evaluation procedures used in this study have been fully explained to players and coaches. All players had at least one year of familiarization with RPE scales for the assessment of the perception of training effort and had previously used the NAS-TLX questionnaire in the full version (see a copy on page 30 of this thesis) for the evaluation of training sessions and matches.

Nine and twenty-four different training sessions were monitored, in the Rugby Union and in the Soccer team respectively. Training sessions performed by the rugby union team were classified following the criteria previously detailed by McLaren and colleagues (McLaren et al., 2018). The soccer team's training sessions were classified using the popular "game day minus" format (Akenhead et al., 2016; Malone et al., 5 2015). The rugby union team performed a Skill-based conditioning training session (SkCond) or just a Skills workout. The first type of training included small-sided games or high intensity intermittent game interspersed with semi-opposed, or open gameplay. This kind of training session aimed to improve rugby-union-specific fitness and skills performance and execution of tactics under fatigue. While the other type of training session consisted in individual and team-based drills aimed to develop rugby-union-specific skills, position-specific skills and team attacking and defensive strategy. The soccer team performed the same microcycle plan for all the 4 weeks of training monitoring. We compared the first training session of the week (Rec M-5), in which a differentiated recovery workout was done, with the one held two days before the game (Speed M-2) in which speed training and short-duration high-intensity technical work was done. The recovery session with differentiated training prescription is usually the day of the week when training is least mentally demanding during the week, on the contrary with respect to the last training sessions before a match, that generally required little physical effort, but a high mental commitment in preparation for the upcoming match. Finally, for the rugby team and the soccer team separately, the responses to the questionnaires from each training session were analyzed to obtain a Pearson's correlation value within subjects.

Statistical analysis

To compare the estimated marginal means reported by athletes in the different training types, and so to evaluate the ecological discriminant validity of the differential RPE scales, linear mixed models' analysis was used. Training type was included in the model as fixed effect, while athletes were included as random effect in order to take into account the players response variability. Finally, a different model was created for each scale analyzed as dependent variables. In addition, for each team the responses to the questionnaires were used to obtain a Pearson's within-subjects correlation value for both the M-RPE and the P-RPE scales. Significance was set at an alpha level of $p \leq 0.05$ for all the analysis. All data are reported as mean ± SD. All data were processed using Excel spreadsheets, JASP software (Version 0.17.1), and RStudio software (R Core Team 2022).

RESULTS

Table 7 shows the estimated marginal means per training type obtained comparing the two different training prescriptions by the rugby union team (Skills and Skills Conditioning) and by the soccer team (Recovery-differentiated at match day minus 5 (Rec M-5), and the speed and Skills training session two days from the match (Speed M-2). Moreover, table 8 reports the post hoc analysis results with contrast scores, standard error, upper and lower 95% confidence intervals values, z, and p values. In particular, as previously hypnotized, a significant difference ($p = 0.008$) was detected by the P-RPE scales between the Skills and the Skills Conditioning training sessions type. As regards the perceived mental effort, no significant differences were measured between the two types of training in the rugby union team. The results obtained in the three unidimensional scales are plotted in Figure 12, the M-RPE, the P-RPE and the O-RPE, respectively. Moreover, in the soccer team analysis a significant difference ($p = 0.00192$) was detected by the M-RPE scales between the Recovery and the Speed training sessions. As regards the perceived physical effort, no significant differences were found between the two types of training in the soccer teams. The results of the assessment obtained by the soccer team are plotted in Figure 13. The hypothesis that there was a difference in mental load between the two types of training prescriptions was confirmed.

Sport	Scale	Training Type	Estimate	SE	95% CI	
					Lower	**Upper**
Rugby Union	M-RPE	SkCond	3.812	0.284	3.255	4.369
		Skills	3.627	0.297	3.044	4.209
	P-RPE	SkCond	4.616	0.325	3.979	5.254
		Skills	3.515	0.367	2.795	4.235
Soccer	M-RPE	Speed M-2	3.71	0.308	3.08	4.33
		Rec M-5	2.78	0.307	2.15	3.40
	P-RPE	Speed M-2	3.87	0.281	3.31	4.43
		Rec M-5	3.45	0.280	2.89	4.01

Table 7. *Estimated marginal means for each of the scales in the two different types of training prescription performed by the rugby union athletes and by the soccer players. SkCond: Skills Conditioning. Speed M-2: Speed and tactical training session performed two days before the game. Rec M-5: Recovery session with differentiated training prescription performed five days before the game.*

Sport	Contrast	Estimate	SE	95% CI		z	p†
				Lower	Upper		
Rugby Union	M-RPE	0.185	0.320	−0.442	0.812	0.578	0.563
	P-RPE	1.102	0.414	0.290	1.913	2.660	0.008***
Soccer	M-RPE	0.932	0.246	0.229	16.354	-3.796	0.002***
	P-RPE	0.415	0.292	-0.422	125.146	-1.419	0.715

Table 8. *Contrast values, which are the post hoc comparisons of the results of the same scales in the two different types of training prescription. In the rugby team the contrasts were between Skills and Skills Conditioning training type, while in the soccer team the contrasts were between M-2 and M-5, match day minus two and five days, respectively Speed and Recovery training type. † P-values are not adjusted. * Significant difference (p < 0.05).*

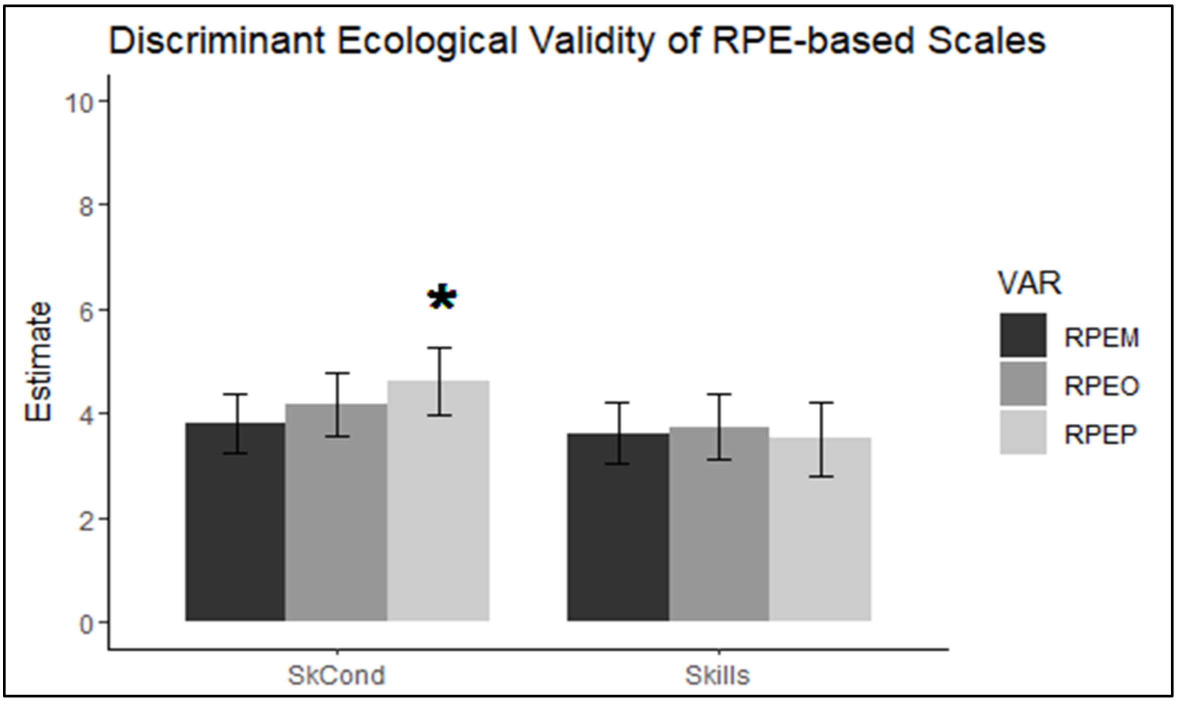


Figure 12. *Estimated marginal means of the Linear mixed models used to assess the Discriminant Ecological Validity of the P-RPE scale, in the rugby union team of Skills and Skills Conditioning training sessions. * Significant difference (p < 0.05).*

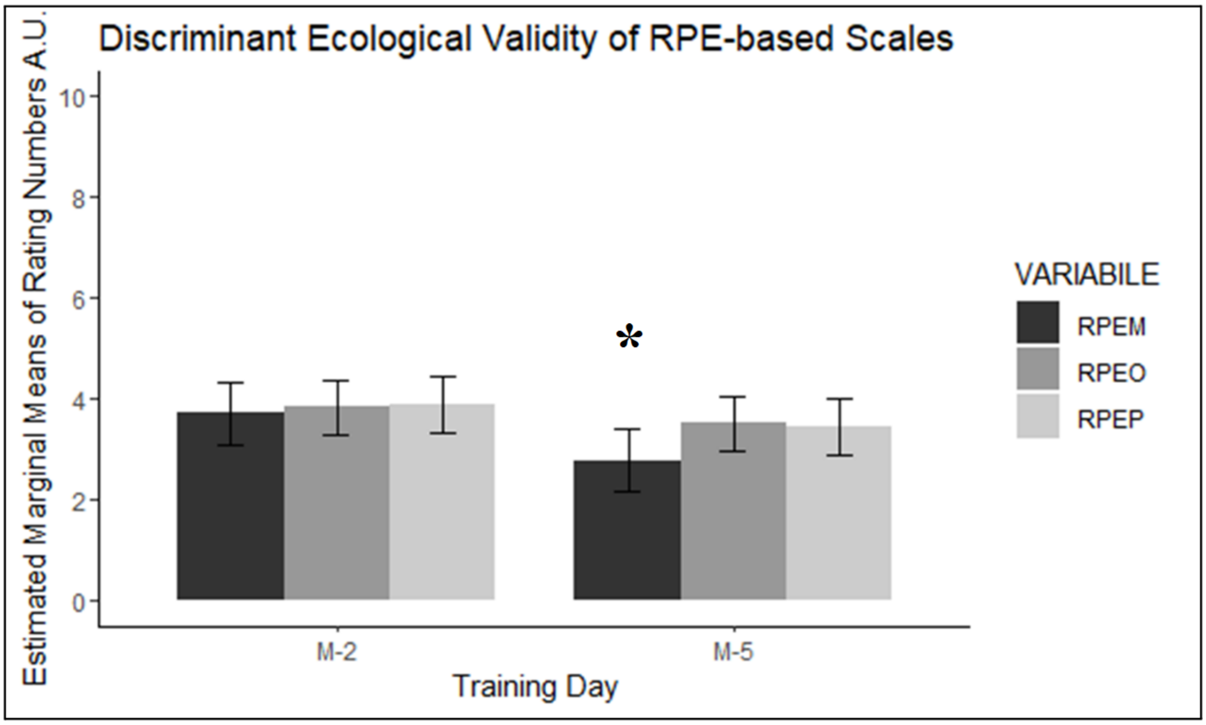


Figure 13. *Estimated marginal means of the Linear mixed models used to assess the Discriminant Ecological Validity of the M-RPE scale, in the soccer team of Recovery M-5 and Speed M-2 training sessions. * Significant difference ($p < 0.05$).*

Within-subject correlations obtained by analyzing the rugby team data, show a correlation value of $r = 0.647$ and $p < 0.001$ and $r = 0.795$ and $p < 0.001$ for the M-RPE and for the P-RPE scales, respectively. Similarly, the within-subject correlations obtained by analyzing the soccer team data, show a correlation value of $r = 0.864$ and $p < 0.001$ and $r = 0.894$ and $p < 0.001$ for the M-RPE and for the P-RPE scales, respectively.

DISCUSSION

The results of the present study confirmed the hypotheses made a priori by the researchers. The P-RPE scale proved to be able to discriminate workouts with different physical loads performed by rugby players. The M-RPE scale also proved to be reliable in discriminating workouts with a different mental demand such as those performed by the soccer team monitored in the present study. Regarding the rugby union team, the difference between the skills conditioning training session and the skills training sessions was 1,1 a.u. in favor of the skills conditioning training session typology for the Physical-RPE score. Compared with the data presented by McLaren and colleagues in 2017 (McLaren et al., 2017), the difference in perceived exertion between these two workouts appears to be smaller. The colleagues had used a centile scale, obtaining measures of about 5 points for the skills conditioning training type, and about 2 points for the skills training type. Specifically for the latter type of training there is the greatest difference (1.6 a.u.) with the data from the present study.

Moreover, the within-subjects correlation results obtained from monitoring the rugby union and the soccer teams showed all large to very large relationships between the M-RPE and the P-RPE scales and the respective criterion measure (William G. Hopkins et al., 2009). The results of the relationship between the criterion measure and the two differential scales of RPE used in the present study is in agreement with the relationships found by Campos-Vazquez e colleagues between RPE and Heart rate (Campos-Vazquez et al., 2015), and with the relationship found by Impellizzeri and colleagues and by Gibson and colleagues between RPE training load and training impulse (Gibson et al., 2022; Impellizzeri et al., 2004). The scales appear to have good agreement with respect to the criterion measure, even considering the within-subjects variability in the ability to answer rating scales questions. Further research is needed to investigate the relationship between the physical and mental loads athletes are exposed to during training and competition. Considering a wider range of training session types or athletes from different sports might be interesting to investigate in future research.

Study 3 - Test-retest Reliability (Intraclass Correlation)

INTRODUCTION

After two first validity studies of this doctoral thesis, in which the construct validity against a criterion measure was tested in study one, and the discriminant validity of the scales in differentiating different workloads in study two, it is necessary to test the reliability of the two new RPE differential scales of perception of physical exertion and mental exertion. It is interesting to investigate whether athletes are able to consistently evaluate the same repeated training performed twice. To test the reliability of the differential RPE scales in the field environment, a test-retest study design was set, and Four National levels teams were recruited. Two semi-professional volleyball teams and two professional handball teams were involved in this third study of the thesis. Generally, test-retest reliability is a measure of reliability obtained by administering the same test twice over a period to the same group of individuals. In our case the test is represented by the administration of the questionnaires after performing the same identical workout two times. The scores from measurement 1 and measurement 2 can then be correlated to evaluate the stability over time of the questionnaires. In this field reliability study the period between the first and the second test is seven days. The hypothesis of this study was that the athletes of both the two handball teams and the two volleyball team will be able to concordantly evaluate the same workout repeated twice with both two differential RPE scales. In other words, it is hypothesized that both scales results to have good reliability when used by the athletes involved in the present study to evaluate a physical workout of their routine.

METHODS

To test the reliability of the two differential RPE scales four different team sport teams were recruited. A test-retest study design was run. The coaches were asked to share the training program to identify which type of training most closely matched the needs of the research. Mid-week physical training in which strength and power training was performed was chosen for all teams. There was no intention to modify in any way the training program already planned by the coaches and physical trainers in order to make the study as much ecological as possible.

After giving informed consent, all participants completed the questionnaires 30 minutes after their regular physical training sessions. After completing the general part of the questionnaire, participants rated the overall difficulty of the training session (O-RPE), then participants rated their training with the physical and mental demand scales of the NASA-TLX questionnaire and with the differentiated RPE rating scales for Physical exertion and for Mental exertion, in random order.

All these procedures, as well as the total duration of the training session and the time between the end of the training session and the completion of the questionnaires were kept strictly the same between the first and second surveys.

Participants

Fifty-four (handball n= 30 and volleyball n=24) athletes were asked to repeat twice the same identical training session 7 days apart. In agreement with the coaches of the respective teams, two consecutive microcycle workouts involving the same training prescription were chosen to be monitored to test the reliability of the scales. Two strength and conditioning weekly workouts have been evaluated. Circuit training method and intermittent Small-sided games were adopted, for the volleyball and handball teams, respectively. Intensity, duration and all the contextual factors, such as environment and motivation, were maintained identically between the two workouts monitored for all teams. After the warm-up and the physical conditioning part of the training session, during the water break before the final technical part of the training session, each player was asked to answer the questionnaires without influencing or communicating with each other. Forty athletes completed both the workout and filled properly all the questionnaires and were included in the final analyses.

Statistical analysis

Test-retest reliability was also tested with the Bland Altman method and using the Intraclass Correlation Coefficient (ICC) test–retest, based on a two-way mixed model effect, absolute agreement, and single measurements. In accord with Koo and colleagues ICC values lower than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and higher than 0.90 were classified as poor, moderate, good, and excellent reliability, respectively (Koo & Li, 2016). Lower and upper limit bounds of the 95% CIs were also reported. Significance was set at an alpha level of $p \leq 0.05$ for all the analysis. All data are reported as mean ± SD. All data were processed using Excel spreadsheets, JASP software (Version 0.17.1), and RStudio software (R Core Team 2022).

RESULTS

The M-RPE scores were highly correlated (r=0.752, p<0.001, ES 0.977) between the two training sessions. Slightly lower, but significant were the results of the P-RPE scales (r=0.647, p<0.001, ES 0.770). Test-retest reliability indicates that both the P-RPE and the M-RPE scale are reliable. ICC resulted good to moderate, for the M-RPE and the P-RPE scales, respectively. Results are reported in Table 9. Furthermore, looking at the Bland Altman Plot no evident systematic and casual errors can be detected (see Figure 16 and 15 for details). In Table 10 are reported the limit of agreement between the two data collections. The mean difference was -0.1 and 0.163 for the M-RPE and the P-RPE, respectively.

Scales	Point Estimate	Lower 95% CI	Upper 95% CI	Reliability Level
RPE-M	0,752	0,577	0,861	Good
RPE-P	0,649	0,426	0,798	Moderate

Table 9. *Intraclass Correlation: Type: ICC3,1 Two-way mixed effects, consistency, single rater/measurement. Note. 40 subjects and 2 raters/measurements. ICC type as referenced by Shrout & Fleiss (1979).*

Below the Bland-Altman Plots for each variable are depicted.

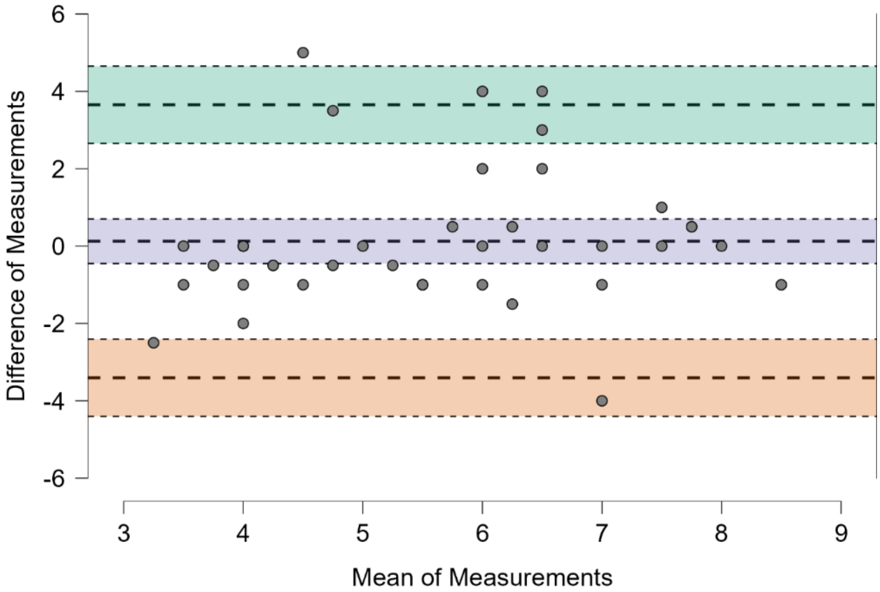


Figure 14. *Bland-Altman plots between the two Overall RPE measurement. The horizontal axis represents the mean of the rated Overall RPE and the vertical axis, the difference between the two training sessions scores. Thick dotted line shows the median difference (close to zero) and the two LoA (upper and lower). Thin dashed lines show the 95% limits of agreement (LoA).*

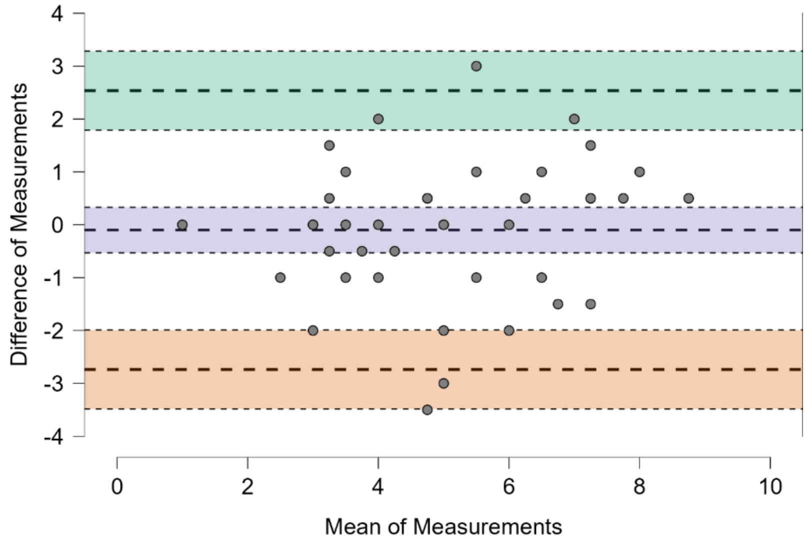


Figure 15. *Bland-Altman plots between the two Mental RPE measurement. The horizontal axis represents the mean of the rated Mental RPE and the vertical axis, the difference between the two training sessions scores. Thick dotted line shows the median difference (close to zero) and the two LoA (upper and lower). Thin dashed lines show the 95% limits of agreement (LoA).*

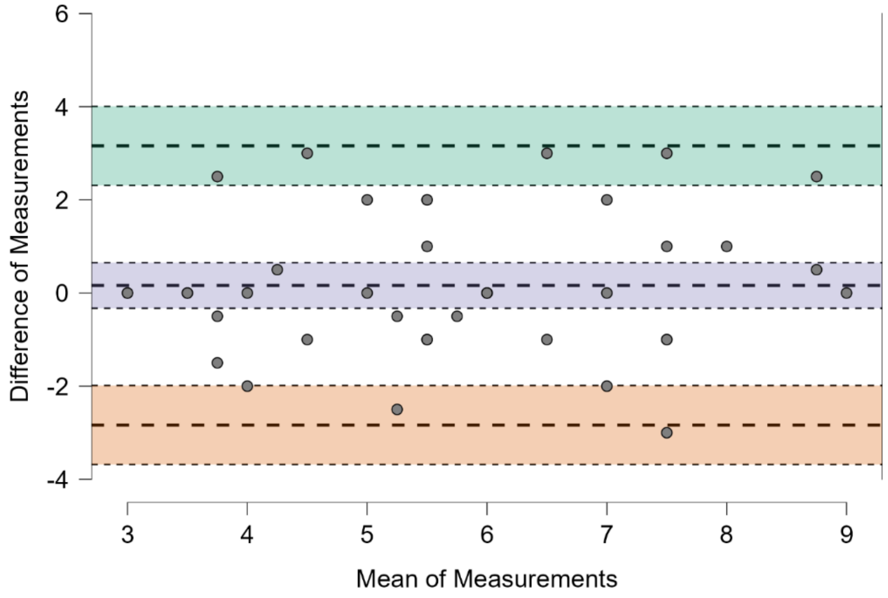


Figure 16. *Bland-Altman plots between the two Physical RPE measurement. The horizontal axis represents the mean of the rated Physical RPE and the vertical axis, the difference between the two training sessions scores. Thick dotted line shows the median difference (close to zero) and the two LoA (upper and lower). Thin dashed lines show the 95% limits of agreement (LoA).*

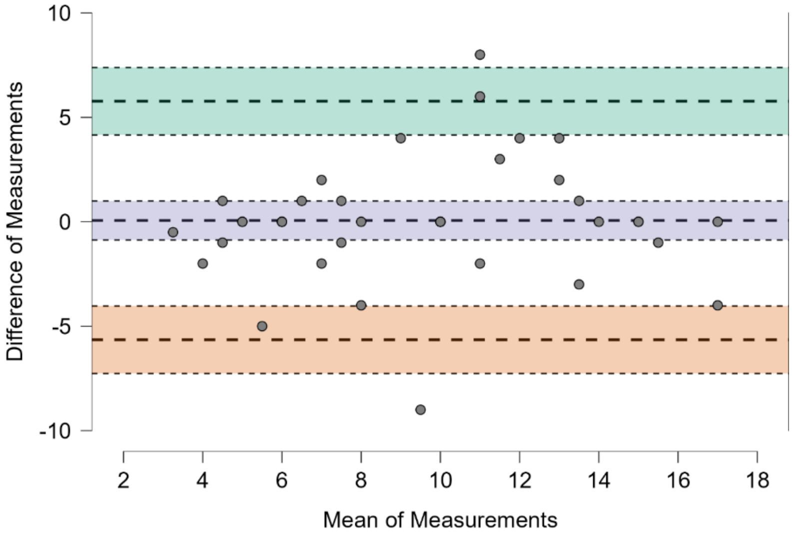


Figure 17. *Bland-Altman plots between the two Mental Demand measurement by NASA-TLX questionnaires. The horizontal axis represents the mean of the rated Mental Demand and the vertical axis, the difference between the two training sessions scores. Thick dotted line shows the median difference (close to zero) and the two LoA (upper and lower). Thin dashed lines show the 95% limits of agreement (LoA).*

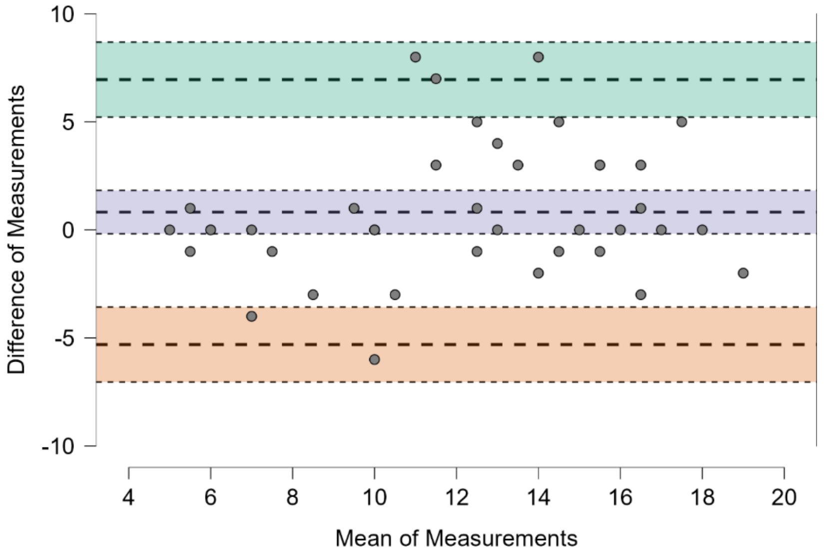


Figure 18. *Bland-Altman plots between the two Physical Demand measurement by NASA-TLX questionnaires. The horizontal axis represents the mean of the rated Physical Demand and the vertical axis, the difference between the two training sessions scores. Thick dotted line shows the median difference (close to zero) and the two LoA (upper and lower). Thin dashed lines show the 95% limits of agreement (LoA).*

Below in Table 10 the Bland-Altman tables for each variable are reported.

Overall RPE:

Bias & Limits	**Point Value**	**Lower 95% CI**	**Upper 95% CI**
Mean difference + 1.96 SD	3.653	2.656	4.650
Mean difference	0.125	-0.451	0.701
Mean difference - 1.96 SD	-3.403	-4.400	-2.406

Mental RPE:

Bias & Limits	**Point Value**	**Lower 95% CI**	**Upper 95% CI**
Mean difference + 1.96 SD	2.537	1.792	3.282
Mean difference	-0.100	-0.530	0.330
Mean difference - 1.96 SD	-2.737	-3.482	-1.992

Physical RPE:

Bias & Limits	**Point Value**	**Lower 95% CI**	**Upper 95% CI**
Mean difference + 1.96 SD	3.160	2.313	4.007
Mean difference	0.163	-0.327	0.652
Mean difference - 1.96 SD	-2.835	-3.682	-1.988

Mental Demand of NASA-TLX questionnaire

Bias & Limits	**Point Value**	**Lower 95% CI**	**Upper 95% CI**
Mean difference + 1.96 SD	5.773	4.159	7.387
Mean difference	0.063	-0.869	0.994
Mean difference - 1.96 SD	-5.648	-7.262	-4.034

Physical Demand of NASA-TLX questionnaire

Bias & Limits	**Point Value**	**Lower 95% CI**	**Upper 95% CI**
Mean difference + 1.96 SD	6.957	5.224	8.690
Mean difference	0.825	-0.176	1.826
Mean difference - 1.96 SD	-5.307	-7.040	-3.574

Table 10. *Limit of agreement for all the comparison between the same vatiables in the two different occasions. Mean difference and upper and lower Confidence Intervals limits are reported for the 95%;*

DISCUSSION

The purpose of this part of the research was to test the reliability of the M-RPE and P-RPE scales with athletes in the field environment. The responses of forty players to the two identical training sessions confirm the findings of the previous studies of this thesis and add moderate to good reliability of the scales to the set of results. The results of this study are in agreement with what Scialpi and colleagues found in another study that evaluated the reliability of the Italian version of the Pittsburgh questionnaire on sleep quality in healthy children (Scialpi et al., 2022). Furthermore, similar ranges of intraclass correlation values were found by Scott and colleagues comparing responses to RPE scales assessed with the CR10 scale and the CR100 scale (Scott et al., 2013), or what found by Galeoto and colleagues and by Panuccio and colleagues in assessing reliability for the Italian version of the General Sleep Disturbance Scale (Galeoto et al., 2021, 2023; Panuccio et al., 2020). Renner and colleagues also found in line intraclass correlation coefficients validating the Pittsburgh fatigability scale to assess the perceived mental fatigability (Renner et al., 2021). In contrast, the intraclass correlation coefficient results lower to what Slavich and colleagues found in another study that initially evaluated the reliability of the adult STRAIN questionnaire (Slavich & Shields, 2018), lower respect to what Craig and colleagues found in a study to assess validity and reliability of the International physical activity questionnaire around twelve different country (Craig et al., 2003), and higher values respect what Coppack and colleagues found for the partial score of the Military Physical Loading Questionnaire (Coppack et al., 2022). The reliability of the scales was found to be acceptable despite the limitations of the ecological design compared with laboratory conditions. In addition, the results of this part of the research are quite positive as they were obtained with athletes in the field where optimal control of all contextual factors of training is very difficult. Further research using different training protocols or different populations of athletes is needed.

Study 4 - Discriminant validity in laboratory condition

INTRODUCTION

Further validity testing the scales in laboratory condition is required. In laboratory environment everything is more tightly controlled, including researchers' manipulations, making results more repeatable and useful. In the first three studies in this thesis, field data were collected, so they were quality data in this sense. However, it was assumed, without being able to verify it, that the experience workloads given by the athletes during training and competition were of different types. Furthermore, by automatically including all the types of training performed by the group of athletes who participated in the present research, it was assumed that they covered the whole range of possibilities of different types of training, from training with low physical demand to training with high physical demand, as well as training in which high mental commitment was required and training in which low mental commitment was required.

The main purpose of this study was to test the discriminant validity of physical and mental exertion perception scales in a laboratory condition that was extremely controlled by the researchers.

Then, the intensity of the physical load of a running test was manipulated by the researcher by adjusting running speed on a treadmill. Moreover, the mental demand during exercise was manipulated by including or not including a cognitive test frequently used in the literature for this purpose.

Regarding the physical load intensities, the classification of Norton and colleagues was used (Norton et al., 2010). The authors classified exercise intensities into five different categories: sedentary, light, moderate, vigorous, and high. In the present study, light and vigorous intensities were chosen. These intensities correspond to an "easy" and an "hard" perceived exertion according to Borg's CR10 scale adapted by Foster and colleague (Foster et al., 2001). In addition, objective measures of metabolic consumption (1.6<3 METs and 6<9 METs), percent of HR relative to maximal (40<55% HRmax and 70<90% HRmax), HR recovery (20<40% HRR and 60<85% HRR), and maximal oxygen consumption (20<40% VO2max and 60<85% VO2max) are associated with light and high intensity of exercise respectively. Light intensity can be sustained for at least 60 minutes while vigorous intensity no more than 30 minutes. Following these guidelines, the intensity of exercise was set.

Regarding the mental load, a test frequently used in the literature was chosen. This test is a cognitive demand for the athlete in addition to the physical demand of the run. Specifically, the free memory recall test was adopted. This test was previously used in various scientific research contexts (Gattoni et al., 2023; Pesce et al., 2009; Gabriele Russo et al., 2019). Hence, Combining the two running intensities with the cognitive test in four experimental conditions, a discriminant validity laboratory study to test the physical and mental exertion rating scales was conducted. The hypothesis of the present study was that both the two new differential RPE scales are able to differentiate different types of training loads in which the physical load and the mental load were modulated ad hoc. We expect different scores in the two mental and physical RPE scales for each type of training created for the present study.

METHODS

Participants

To run study 4, another 30 athletes (track & field n = 4, team sport n = 7 and fitness n=19) were tested in the laboratory. A total of 20 males and 10 females voluntarily participated in the present research, providing written consent. They were all trained to international level athletes and free from injury in the twelve months prior to the study (McKay et al., 2022). All the participants were used to working out at least three times per week in the past 3 months from the beginning of the present research. All the characteristics of the sample groups are described below in Table 11.

Sport	N	Gender	Age [year]	Stature [cm]	Weight [Kg]	Level	Monitoring Duration
4 Track & Field 7 Team Sport 19 Fitness	30	20 m 10 f	27.2 ± 3.9	171.8 ± 6.0	68.2 ± 8.1	2 Inter-national 8 National 20 Amateur	4 different training sessions in a single visit

Table 11. *Details of the participant at the present research are reported.*

Ethics Committee of the University of Bologna approved all procedures used in this research. Throughout the duration of the laboratory experiments, the true purpose of the research was masked, and the athletes were told that the purpose was to test the congruence of the scales with the type of short training performed.

Experimental design and procedures

In a single laboratory visit, four different training conditions were tested in a cross-counterbalanced design study in which both physical and cognitive load were modulated through different running speeds and with the presence of a free recall memory test. The design was created in agreement with and similar to the previous study by Mehta and colleagues (Mehta & Agnew, 2015). After completing informed consent and a short questionnaire with biographical and anthropometric information, the athletes performed a standardized warm up already used in previous studies (Bartolomei et al., 2021; Nigro & Bartolomei, 2020), consisting of 5 minutes of mild aerobic run at a self-regulated speed and dynamic muscle activation and mobility exercises. During the last two minutes of the aerobic run a two minute familiarization with the free memory recall test was run. A submaximal running test was conducted on a treadmill (Cosmed, Italy) starting from the speed of 8 km/h and increasing it by 1 km/h every two minutes until 85% of the theoretical maximum heart rate, estimated by the formula 220 - age, was reached. Using the graphical interpolation method, two speeds corresponding to 80% and 50-60% of the theoretical maximum heart rate were estimated per each athlete. Four 5-minute workouts were performed in random order: two at high speed, and two at low speed, with and without the cognitive test. Immediately upon completion of the exercise, subjects were asked to leave the treadmill and sit down. If they had taken the cognitive test, they were asked to write down all the words they remembered in 90 seconds, at the end of which time they were administered the rating scales of the physical and mental exertion they had just performed. A full recovery of ten minutes was allowed after each test and between the submaximal test and the workouts. Throughout the visit, cardiac responses were monitored with a heart rate monitor (Garmin, Forerunner 245). The entire lab visit lasted about 90 minutes. The full experimental design is depicted below in Figure 19.

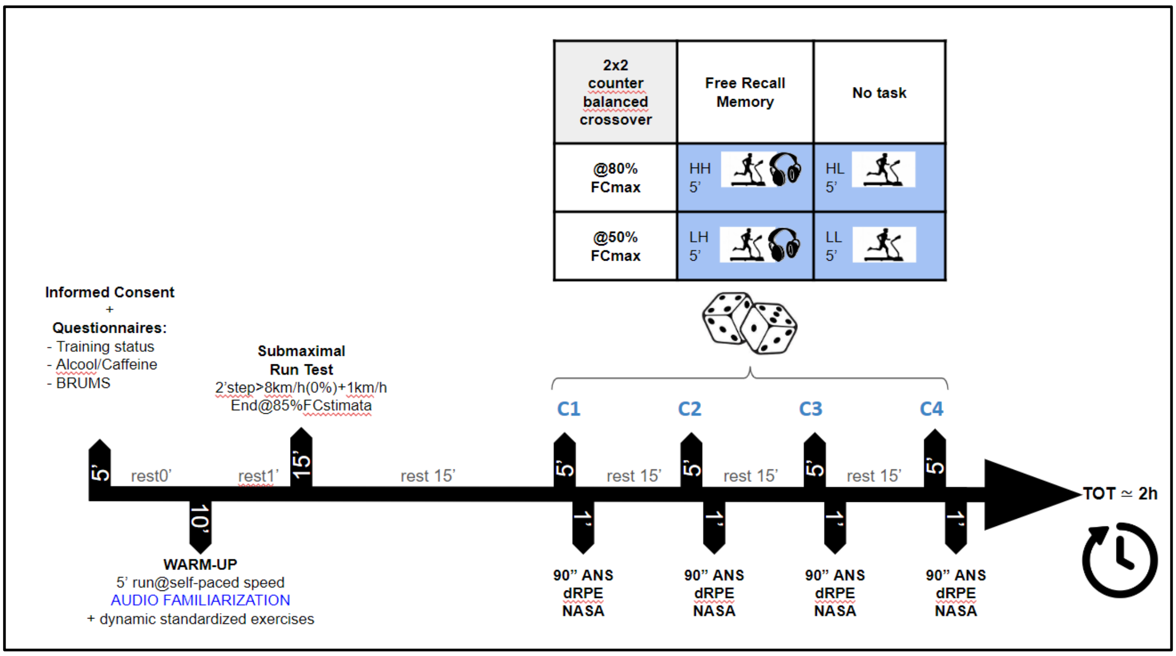


Figure 19. Experimental protocol of the cross-counterbalanced research design; BRUMS = Brunnel Mood Scale; HR = Heart rate; ANS = Answers of Free Memory Recall Test; dRPE = differential Rating of Perceived Exertion scales (Physical and Mental); NASA = NASA-TLX Questionnaire; TOT = total time; C1, C2, C3 and C4 = experimental condition number;  *= Free Memory Recall Test;*  *= running;*  *= randomized;*  *= Total time;*

Free memory recall test/Cognitive task

During sports practice the constant mental demands, such as recognizing game situations or deciding what to do before the opponent, are an example of the psychological performance load that athletes are exposed to every practice or game. To reproduce a cognitive demand similar to that in the field, it was decided to administer a free-memory recall test to athletes, following the procedures already used by Pesce and colleagues, by Nielsen and colleagues and also by Russo and colleagues (Geertsen et al., 2016; Pesce et al., 2009; G. Russo et al., 2019; Russo et al., 2021, 2019). From the list of words provided by Paivio, all words with below-average value for the following criteria were discarded: age of acquisition, familiarity, imaginability and concreteness (Paivio et al., 1968). In addition, only words composed of only two syllables were selected (Fernandes & Moscovitch, 2000). Finally, two groups of twenty words and one group of ten words were created specifically for the experiment of the experimental study. This test has previously been used in visual form, but in this research, it was used in the auditory version, in accordance with the procedures used by Epling and colleagues. Words were played every 15 seconds, for a total of 5 minutes per audio track, while 8 words every 15 seconds were used in a 2-minute audio track for familiarization with the dual task of running and listening performed during warm-up (Coles & Tomporowski, 2008). The words were remembered and written on a piece of paper immediately at the end of the 5 minutes of exercise, sitting on a chair with a small table attached. Words were considered correct if they were present in the to-be remembered list, with minor pronunciation errors and plural-singular substitutions ignored.

Statistical Analysis

A within-subjects correlation was performed according to the methods proposed by Bland and Altman in 1995 (Bland & Altman, 1995). According to Hopkins et al., correlation coefficients of 0.1, 0.3, 0.5, 0.7, and 0.9 were interpreted as small, moderate, large, very large, and extremely large relationships, respectively (Hopkins, 2000). Intraclass Correlation Coefficients based on a two-way mixed effects (3,k) were also used to test reliability of the two new scales. ICC values lower than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and higher than 0.90 were classified as poor, moderate, good, and excellent reliability, respectively (Koo & Li, 2016). A 2X2 ANOVA for repeated measures was used to establish the discriminant validity of the scales in the four different experimental training conditions. If the interaction was found to be significant, Bonferroni's correction was applied. Significance was set at an alpha level of $p \leq 0.05$ for all the analysis. All data are reported as mean ± SD. All data were processed using Excel spreadsheets, SPSS software (version 25, IBM Corporation, Armonk, NY, USA) and JASP software (Version 0.17.1).

RESULTS

Hereafter by convention we will call C1 the experimental condition in which the cognitive task was performed while high speed run; C2 the experimental condition in which the high speed run was performed without the cognitive task; C3 the experimental condition in which the cognitive task was performed while low speed run; C4 the experimental condition in which the low speed run was performed without the cognitive task.

A within-subject correlation analysis was run between the four experimental condition answers at the mental and physical rating scales. Positive partial correlation was found for both the two mental effort scales and the two physical effort scales, $r=0.903$, $p<0.001$ for the mental and $r=0.704$, $p<0.001$ for the physical, respectively. More details are reported in the following Table 12. Furthermore, the two positive relationships found are depicted in scatter plots in Figure 20 and in Figure 21.

Model	**Beta in**	**t**	**P value**	**Partial Correlation**	**Collinearity**		
					Tollerance	VIF	Minimum Tollerance
Mental	0.896	19.856	<0.001	0.903	0.818	1.223	0.501
Physical	0.804	9.357	<0.001	0.704	0.529	1.890	0.465

Table 12. *Within-subject correlation analysis between the two Mental effort scales and between the two physical effort scales.*

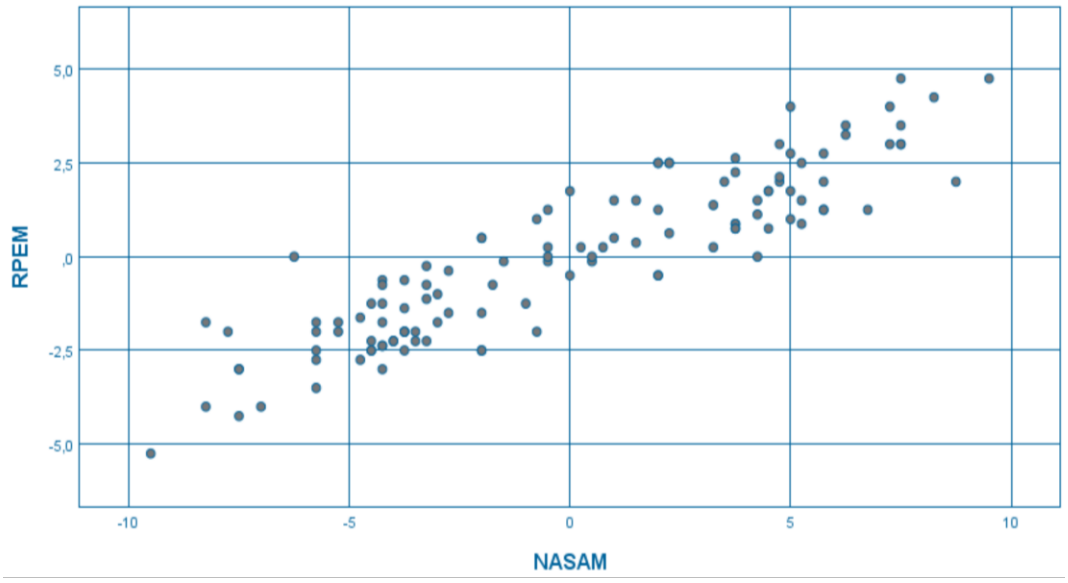


Figure 20. *Partial correlation between NASA-TLX Mental and Mental RPE.*

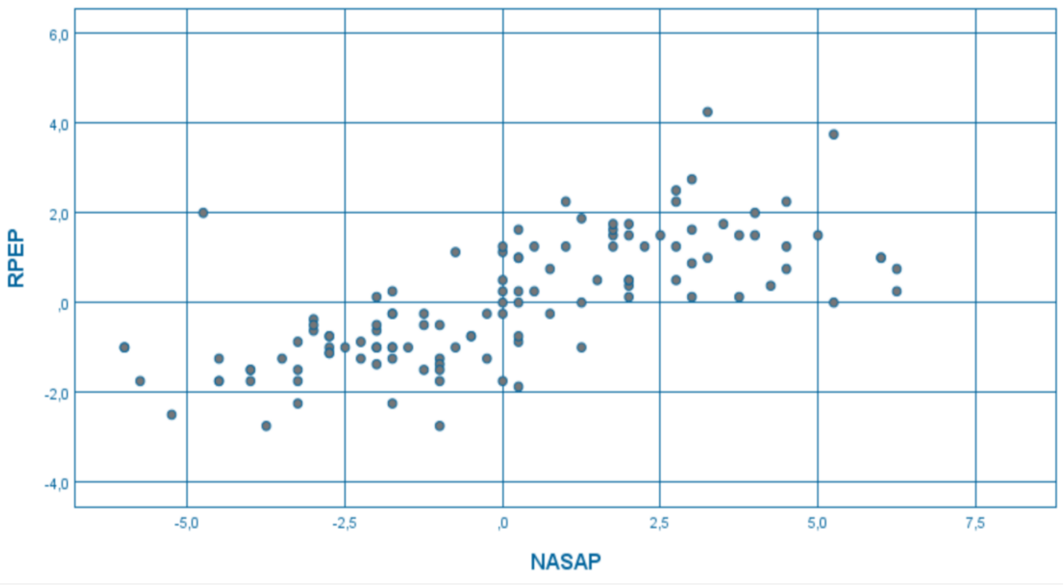


Figure 21. *Partial correlation between NASA-TLX Physical and Physical RPE.*

Mean Overall-RPE scores in C1 were 4.78 ± 1.12 a.u., the Mental-RPE scores were 5.20 ± 1.88 a.u., the Physical-RPE scores were 3.55 ± 1.29 a.u., the NASA-TLX Mental were 11.97 ± 3.77 a.u., and the NASA-TLX Physical were 8.50 ± 4.15 a.u.. In addition, an average of 14.37 ± 2.87 word has been recalled by the participant in this experimental condition. In experimental condition C2 a mean of 5.12 ± 1.20 a.u. were scored for the Overall-RPE, an average of 2.00 ± 1.48 a.u. were scored for the Mental-RPE, an average of 4.58 ± 1.64 a.u. were scored for the Physical-RPE, an average of 4.03 ± 2.75 a.u. were scored for the NASA-TLX Mental, and an average of 9.23 ± 3.96 a.u. were scored for the NASA-TLX Physical. Mean Overall-RPE scores in C3 were 2.13 ± 0.77 a.u., the Mental-RPE scores were 4.82 ± 2.07 a.u., the Physical-RPE scores were 1.87 ± 0.95 a.u., the NASA-TLX Mental were 10.57 ± 4.16 a.u., and the NASA-TLX Physical were 4.47 ± 2.24 a.u.. In addition, an average of 14.40 ± 3.35 word has been recalled by the participant in this experimental condition. In experimental condition C4 a mean of 2.17 ± 0.91 a.u. were scored for the Overall-RPE, an average of 1.17 ± 1.13 a.u. were scored for the Mental-RPE, an average of 2.20 ± 1.13 a.u. were scored for the Physical-RPE, an average of 2.67 ± 2.02 a.u. were scored for the NASA-TLX Mental, and an average of 4.23 ± 2.43 a.u. were scored for the NASA-TLX Physical. All these results are depicted in Figure 22, Figure 23, and Figure 24.

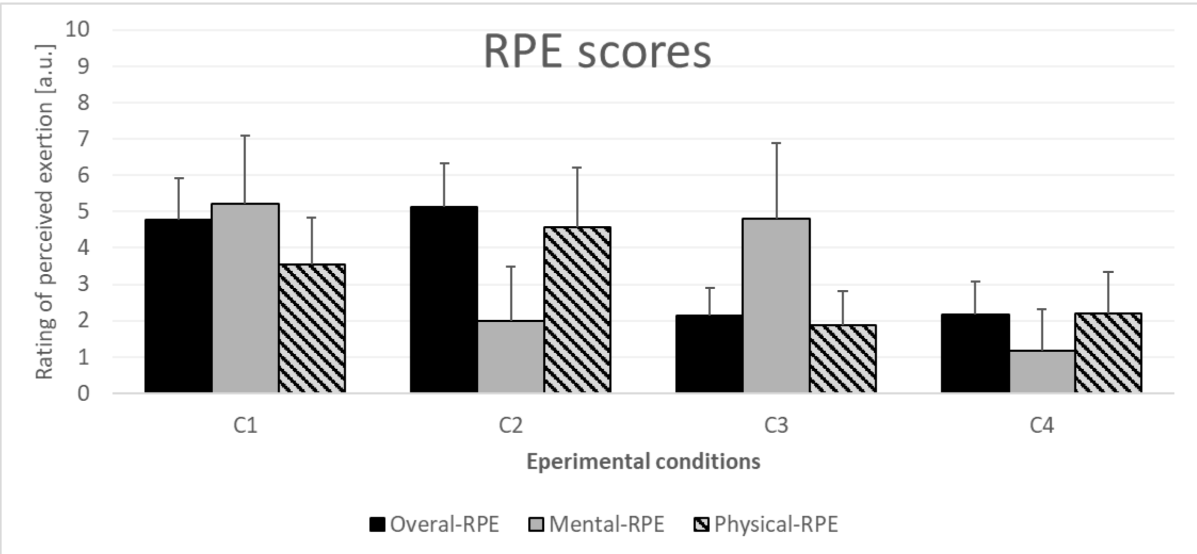


Figure 22. *Multiple barplot illustrates the Overal-RPE, Mental-RPE and Physical-RPE scores in the four experimental conditions (C1-4). Data are presented as mean and error bars represents the standard deviation.*

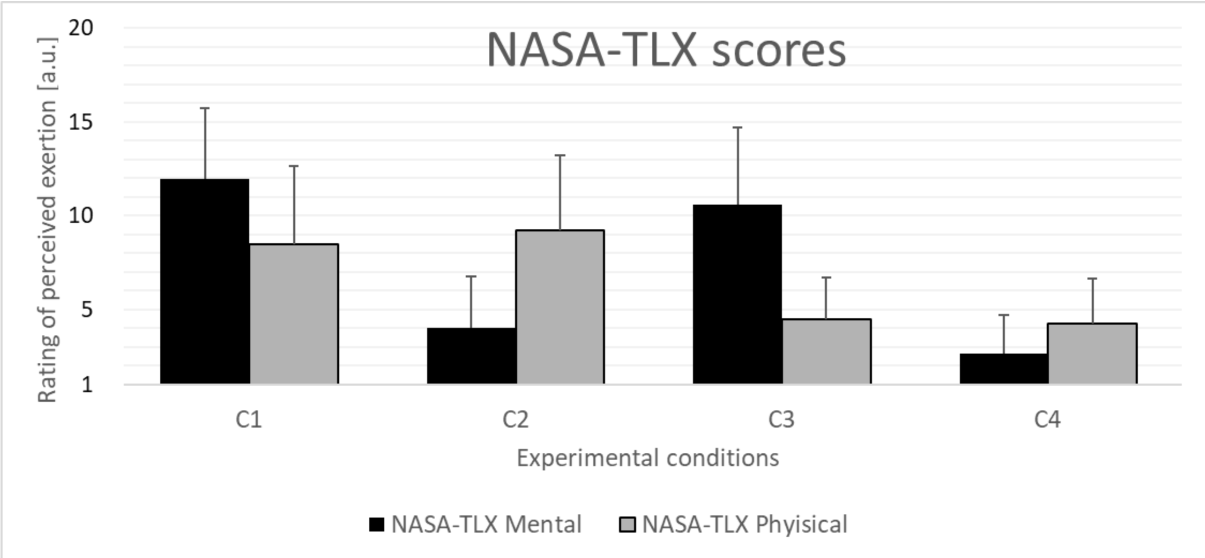


Figure 23. *Multiple barplot illustrates the NASA-TLX Mental and the NASA-TLX Physical scores in the four experimental conditions (C1-4). Data are presented as mean and error bars represents the standard deviation.*

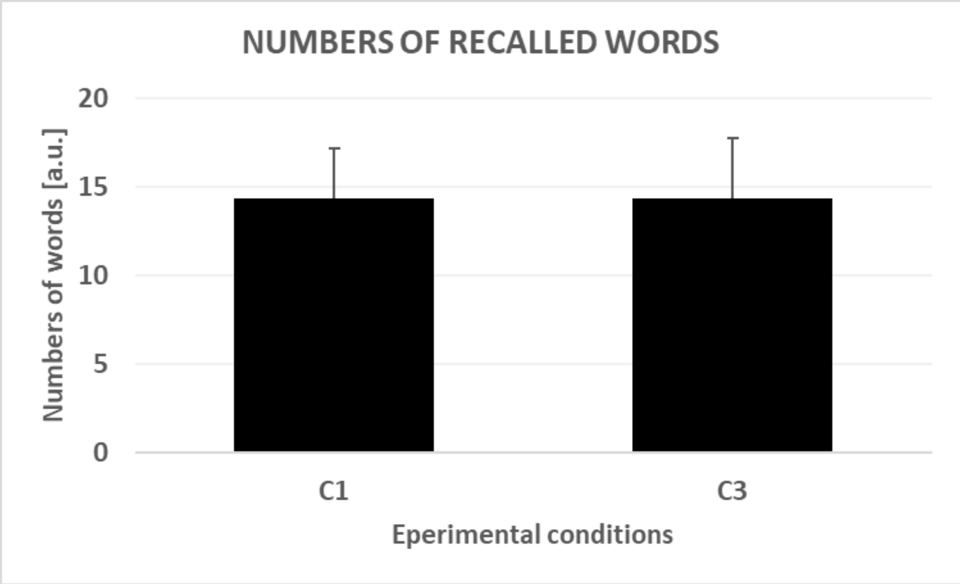


Figure 24. *Barplot illustrates the numer of recalled words after the Free memory recall test performed in C1 and C3 experimental conditions. Data are presented as mean and error bars represents the standard deviation.*

A repeated measures ANOVA was performed to compare the effect of the cognitive load added on the physical task of running at two different speeds, high at 80% and low at 50-60% of the maximal HR respectively, on the Overall-RPE score. There was a statistically significant main effect between the two high speed and the two low speed condition $F(29, 1) = 208.75$, $p < 0.001$. On the contrary, there was not found a statistically significant main effect between the two experimental conditions with and the two without the cognitive task $F(29, 1) = 1.66$, $p = 0.208$. Same results were found for the interaction between the Mental and the Physical Factors of the four experimental conditions $F(29, 1) = 1.97$, $p = 0.171$.

Repeated measure ANOVA for the Mental-RPE scores was statistically significant in the two main effect of Mental factor $F(29, 1) = 83.73$, $p < 0.001$, and of the Physical factor $F(29, 1) = 8.37$, p

= 0.007 respectively. No statistically significant interaction between the two factor was found. Furthermore, repeated measure ANOVA for the Physical-RPE scores was statistically significant in the two main effect of Mental factor $F(29, 1) = 72.89$, $p < 0.001$, and of the Physical factor $F(29, 1) = 16.85$, $p < 0.001$ respectively. There was a statistically significant interaction between the two factor $F(29, 1) = 8.39$, $p = 0.007$. Post hoc analysis shown statistically significant p value <0.001 for all the comparison except for the comparison between C2 and C4 that results not different $p = 0.667$.

Participants had an estimated maximum HR of 193.3 ±3.99 beat per minute. HR during the last minute was 168.2 ± 11.5 bpm, 164.8 ± 11.6 bpm, 149.1 ± 17.4 bpm, and 143.7 ± 17.7 bpm in C1, C2, C3, C4 experimental condition respectively. The HR after 60 seconds was 121.1 ± 16.7 bpm, 118.6 ± 15.0 bpm, 109.1 ± 16.9 bpm, and 108.5 ± 16.1 bpm in C1, C2, C3, C4 experimental condition respectively. HR values during exercise and after one minute from the end of the exercise are graphed in Figure 25 and Figure 26.

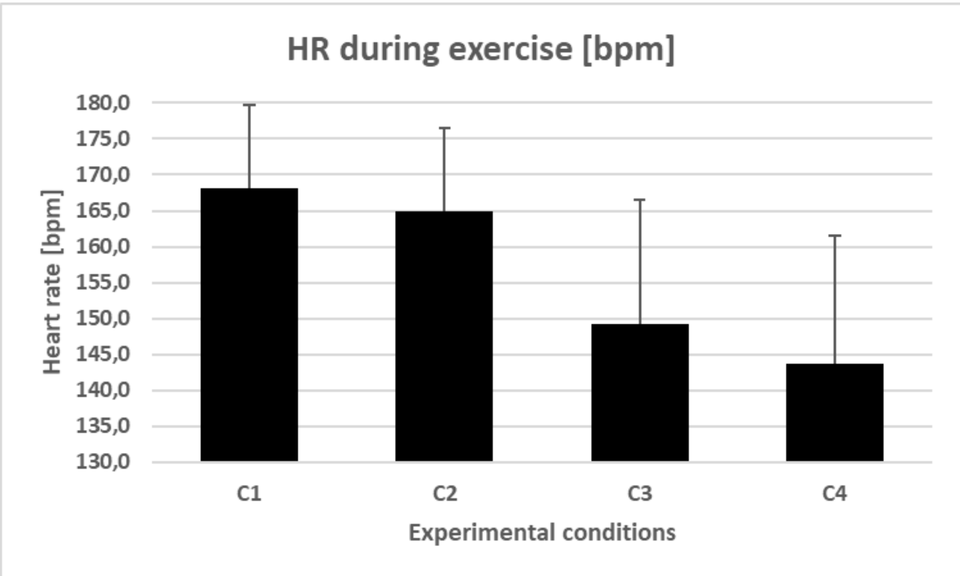


Figure 25. *Bar plot illustrates the average HR during the final minute of run in experimental condition C1, C2, C3 and C4. Data are presented as mean and error bars represents the standard deviation.*

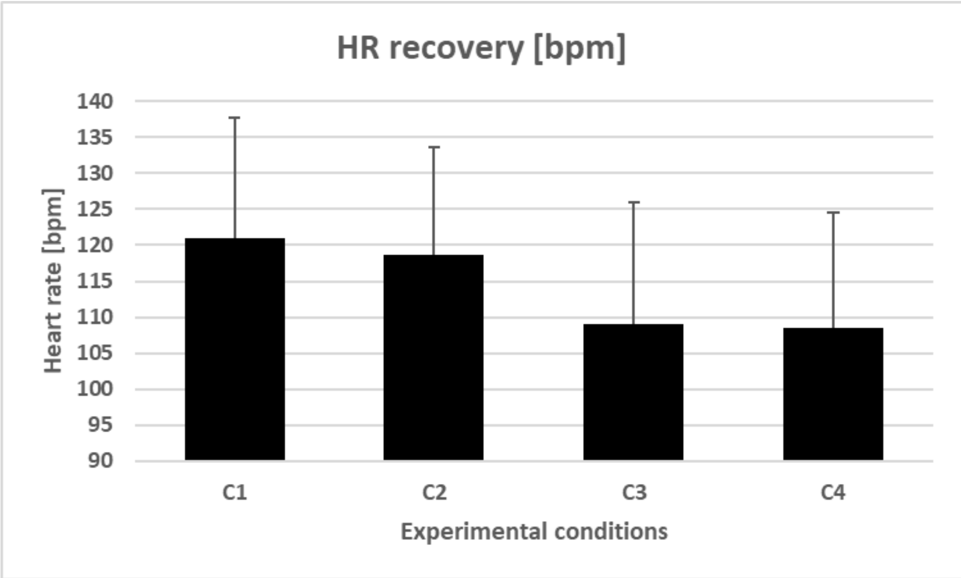


Figure 26. *Bar plot illustrates the average HR during the final minute of run in experimental condition C1, C2, C3 and C4. Data are presented as mean and error bars represents the standard deviation.*

A Repeated Measures ANOVA show that HR during the last minute of the running exercise was significantly different between the four experimental conditions. In particular was found a significant main effect of the Physical intensity of exercise factor $F(27, 1) = 160.702$, $p < 0.001$, and a significant main effect of the Mental factor $F(27, 1) = 16.091$, $p < 0.001$. Moreover, there was a statistically significant interaction between the four experimental conditions $F(27, 1) = 5.070$, p =

0.032. Post hoc analysis shown statistically significant p value <0.001 for all the comparison except for the comparison between C1 and C2 in which p = 0.008.

A Repeated Measures ANOVA show that HR after 60 second was significantly different only between the two conditions with high speed run and the two performed at low speed. In particular was found a significant main effect of the Physical intensity of exercise factor $F(27, 1) = 82.935$, $p < .001$.

DISCUSSION

The within-subjects correlation results confirm the results of previous studies of this thesis. In fact, both RPE scales have a statistically significant correlation ($p<0.001$). Particularly, the Mental-RPE has an extremely large correlation, and the Physical-RPE has a very large correlation according to Hopkins' classification.

In the first two experimental conditions (C1 and C2), those with higher physical intensity, both the Overall-RPE and the Physical-RPE show higher values than the two conditions in which physical intensity demand was lower. Regarding the two experimental conditions in which there is the addition of the cognitive task to the physical running exercise (C1 and C3), Mental-RPE scores were higher than in the two conditions in which the cognitive task was not present (C2 and C4). This indicates that both scales are able to differentiate different types of physical and mental load, respectively. In addition, the non-significant main effect of the Mental-RPE scale justifies the use of a differentiated RPE scales in case it is necessary to quantify the mental load of a training session. The values of heart rate and heart rate recovery behave in agreement between the experimental conditions and are higher in the two high physical intensity conditions than in the two experimental conditions where the physical demand is lower. Furthermore, for the same physical demands the values of Overall-RPE and the heart rate behave in opposite ways. Overall-RPE is lower in the experimental conditions where there is the addition of the cognitive task, while heart rate is higher. Higher internal load response confirm that the demand of the exercise is higher when both tasks are required simultaneously, while the perceived effort was lower. One possible explanation for this behavior is known as the distraction effect typical of endurance disciplines (Meijen et al., 2023). In addition, it can be observed that the values of Physical-RPE are more similar to the Overall-RPE scores, confirming the results of the stepwise linear regression analysis of the study one of this thesis. A limitation of the present study was that all the training conditions were carried out in a single laboratory visit. For this reason, we had to choose very short training sessions in which the physical load and mental load were modulated. However, this reduced the exposure time of the participants to different workloads during training. Future research both in the laboratory and in the field on the ability to differentiate different workloads by these differential RPE scales is needed.

Study 5 - Relationship between Psychological Training Loads and Mood states in élite Athletes.

INTRODUCTION

According to the evidence of the results of the previous four studies of this thesis, we conduct one more study to apply the new differentiated RPE scales in an ecological context. Similarly to how the Overall-RPE, in the form of session-RPE was presented as an alternative training load variable to the classics (Baninster and Edwards TRIMP) used in soccer in the 2004 study by Impellizzeri and colleagues (Impellizzeri et al., 2004). The only difference is that the new RPE-scales proposed in this research are not intended to represent an alternative to classical training load measures but rather to represent an innovation to be able to measure the extra physical loads experienced by athletes during training and competition. The field application of these tools could improve our understanding of the relationships between the internal training loads measured through the differentiated RPE scales. In addition, compared to all the other daily measures commonly used in the field that are, however, lacking in scientific validation, the new differentiated RPE scales could prove to be a useful and valid tool for monitoring extra physical loads the athlete experienced in training and competitions that is easily collected daily and in a non-invasive way. Some of the most commonly used questionnaires in high-level team sport are Brunell's BRUMS questionnaire (a short version of the POMS survey) and the wellness questionnaire proposed by Hooper, which is often used not only in the original version, but adapted to the context in which data will be collected (Brandt et al., 2016; Perri et al., 2021; Quartiroli et al., 2017; Rabbani et al., 2019; Rohlfs et al., 2008; Saidi et al., 2022).

All these adaptations and modification from the original concerns not only the shape of how it looks and the method of administration, but unfortunately often the structures of some items are changed, and validity and reliability are altered making difficult to compare results. The relationships between these indices of athletes' fitness and mood obtained through the administration of daily or weekly questionnaires has been previously investigated. Campbell and colleagues in 2021 tried to identify the predictive capacity of wellness questionnaires on measures of training load using machine learning methods (Campbell et al., 2021). In another research study McLean and colleagues in 2010 examine the changes in neuro- muscular fatigue, perceptual fatigue, and salivary hormones in professional rugby league players during the in-season period. A further aim of this study was to examine differences in these fatigue measures during different length recovery periods between matches (McLean et al., 2010). Clemente and colleagues in 2017 and 2020, and Fernandez and colleagues in 2021 analyzed the microcycle variance using the Hooper index scales amongst positional roles and the relationship between internal training load and Hooper index scores (Filipe M. Clemente et al., 2020; Filipe Manuel Clemente et al., 2017; R. Fernandes et al., 2021).

Hence, the main purpose of this study was to study the relationships between training loads measured with the classical RPE scale and the two differentiated RPE scales against the most common indices of fitness level and mood employed with professional athletes, during the final playoff phase of a competition period. Therefore, a secondary aim of this study was to run a descriptive study with semi-professional athletes to analyze the usefulness of the use of the new RPE differential scales respect to the use of the classic Overall-RPE in training monitoring athletes. The hypotheses were that athletes who accumulate more mental stress, have a greater decline in mood measured before and after the monitoring period with the BRUMS questionnaire and during the period with the wellness questionnaire. Moreover, we hypothesize that differentiating the training load experienced by the athletes in training and in competition could be more useful compared to not differentiating the training load. Finally, similar to what was done in the study one of this thesis, through a regression analysis, the different contribution of physical effort and of the mental effort on the overall effort for each type of training performed by the soccer teams and by the volleyball teams was calculated.

METHODS

Participants

Two soccer teams and two high-level youth volleyball teams participated in this last study of the thesis. First soccer team participated in Serie C national Italian championship in 2022/2023 season. Players were 23.3 ± 3.7 years old, 183.4 ± 6.9 cm high, and 78.0 ± 8.1 kg heavy. 22 players of this team were included in the final analysis. Second soccer team involved in the present study participated in Serie D national Italian championship in 2022/2023 season. Players were 21.8 ± 4.1 years old, 184.0 ± 6.5 cm high, and 79.3 ± 6.8 kg heavy. 19 players of this team were included in the final analysis.

The two volleyball teams involved in the present study were a total of 51 players, 25 males Under 19 and 26 females Under 18. Teams took part of the respective national Italian élite championship in 2022/2023 season. All the players on these two teams were coached by the same staff and followed the same training periodization. Therefore, for these reasons they were merged and analyzed together. Players were 17.6 ± 1.2 years old, 182.9 ± 10.1 cm high, and 73.5 ± 10.0 kg heavy.

Experimental design and procedures

Six weeks and four weeks of training were monitored regarding the two soccer teams. A total of 25 trainings and 21 trainings were monitored, respectively. Seven weeks of training of the two élite volleyball teams were monitored. Such were monitored 54 total workouts between the two teams. The two soccer teams were both engaged in the promotion play-off rounds of Serie C and Serie D national championship, respectively. The youth volleyball teams were engaged in the final round of the regular league, however, which gave access to the national finals in which they participated and won, after the present study took place. During the end of the season, teams should not have any relevant changes in fitness status. Also, it is certainly not the best period of the season to expect improvements from athletes. However, at this sensitive stage of the season any minimum drops in the fitness level of athletes can be very important in achieving the desired performance level. At this final stage of the season, physical stress is high, partly because it is affected by the accumulation throughout the whole year, while mental stress is also very high given the importance of the outcome of the competitions in order to achieve the annual goals set at the beginning of the season.

All athletes completed the questionnaires 30 minutes after every training session occurred during the period monitored for the present research. Participants rated the overall difficulty of the training session (O-RPE), then participants rated their training with the differentiated rating scales for physical exertion (Physical-RPE) and mental exertion (Mental-RPE), in random order. All data were collected using Google Forms specially created for this study. The head coach of each team was asked to keep a detailed diary of every training session sustained.

Daily monitoring questionnaires

At the beginning and at the end of the monitored period, each team filled out a psychological questionnaire to outline the mood profile of each athlete. The ITAMS questionnaire, an Italian validated version of the Brums questionnaire, was administered through a Google Forms created ad hoc (Quartiroli et al., 2017; Rohlfs et al., 2008). A copy of the questionnaire used in the present research is reposted in Appendix XXX. In addition, during the entire durations of the study, players filled out a modified version of Hooper's wellness questionnaire. A copy of the questionnaire used in this study can be found in Appendix XXX (Perri et al., 2021). Finally, after each training session or game, the physical and mental load perception rating scales that are the subject of this validation study were administered.

Training session classification

The soccer team's training sessions were classified using the popular "game day minus" format already used in several studies (Akenhead et al., 2016; Malone et al., 5 2015). The two soccer teams performed the same microcycle plan for all the weeks of training monitored for the present research. The first day of the week, when occurred after a match day was used as resting day. In the first training session of the week (M-5), both teams performed a differentiated recovery workout. In the second training session of the week (M-4) a strength and conditioning training session was added to the tactical workout. In the third training session of the week (M-3) high intensity bouts of small-sided games were adopted as physical conditioning methodology. In the fourth training session of the week (M-2) repeated sprint ability and sprint intermittent training methods were used before a short tactical session. The last training session before the game was dedicated to preparing the game with tactical work combined with agility and reaction workout. The match day occurred in Sunday afternoon for both team in all the weeks monitored for the present study.

Regarding the volleyball teams' workouts, both teams involved in the present research used to have 5 different training type and the match day. Type of training sessions includes: 1) differentiated training, 2) Strength and conditioning training session followed by technical workout or 3) by video plus technical workout, 4) just technical workout or 5) video-based training plus technical workout. Every week monitored for the present study was different from the other weeks. The match day occurred several times during the week in adjunct to the weekend match. Given these reasons the typical week was not presented in time order. In addition, for the same reason it was not possible to classify the workouts with the "match day minus" formula as usual (Lima et al., 2020). The criterion used by Duarte and colleagues differentiates the type of training based on the technical gesture predominantly trained in the session (Duarte et al., 2019), but in our case, it was not possible to obtain this information from the training diaries reported by the coaches. Therefore, to classify the type of training session, the criterion used by Tavares and colleagues was used, in which technical work on the field is differentiated from muscle strengthening work in the gym (Tavares et al., 2018). In addition, the training session in which videos with the players were analyzed has been included.

Statistical analysis

To compare the estimated marginal means of reported differential RPE score by athletes in the different training types, and so to evaluate the relationships between different psychological states scales used by athletes (BRUMS and Wellness questionnaires), linear mixed models' analysis was used. Training type was included in the model as fixed effect, while athletes were included as random effect to take into account the players response variability. To compute the effect size to compare the results of each item of the questionnaire the formula, proposed by Hopkins in 2009 (William G. Hopkins et al., 2009), was used:

$$Effect\ Size = \frac{(Standard\ Deviation\ of\ the\ Fixed\ Effect\ *\ 2)}{Standard\ Deviation\ of\ the\ Random\ Effect}$$

Finally, a stepwise linear regression analysis was performed per each type of training session. The main purpose of this analysis was to isolate the Mental effort and the Physical effort contribution to the Overall-RPE. The Overall-RPE was set as a dependent variable, while the Mental-RPE and the Physical-RPE represented the two covariate variables. The percentage contribution of each covariate on the dependent variable was calculated using the formula proposed by Hopkins in 2010 (Will G. Hopkins, 2010):

$$R^2 = \beta_1 * r_1 + \beta_2 * r_2$$

Significance was set at an alpha level of $p \leq 0.05$ for all the analysis. Effect sizes were interpreted as small, medium or large if they were < 0.2, between 0.2 and 0.5, and above 0.5 respectively according to Cohen guidelines (Cohen, 2013). All data are reported as mean ± SD. All data were processed using Excel spreadsheets, JASP software (Version 0.17.1), and RStudio software (R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/).

RESULTS

A typical weekly microcycle of the two soccer teams involved in the present research is depicted below in Figure 27.

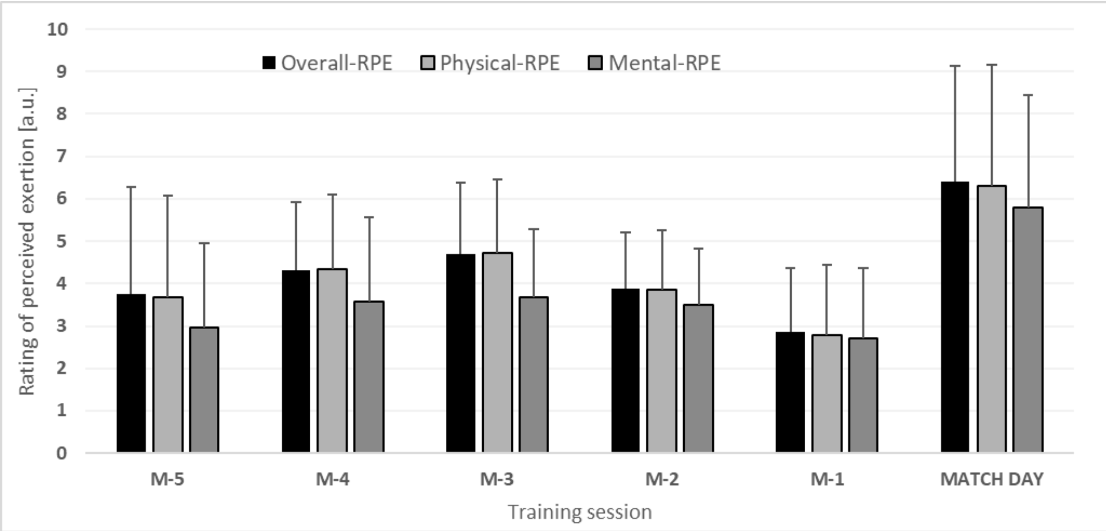


Figure 27. *A typical weekly microcycle performed by the two soccer teams that participated in the present research. M-x formula means match day minus x days, M-5 = recovery day; M-4 = Strength and conditioning + tactical; M-3 = small-sided games; M-2 = speed + tactical; M-1 = agility and reaction + tactical team-run. All data are presented as mean and standard deviations.*

Regarding the volleyball teams' workouts, the average values recorded by type of workout or match in each subscale used in the present research are shown below in Figure 28. Ordering them temporally was not possible because each microcycle was found to be different from the others. In these élite categories matches are scheduled during the week making impossible to perform identically workout routine between different training weeks.

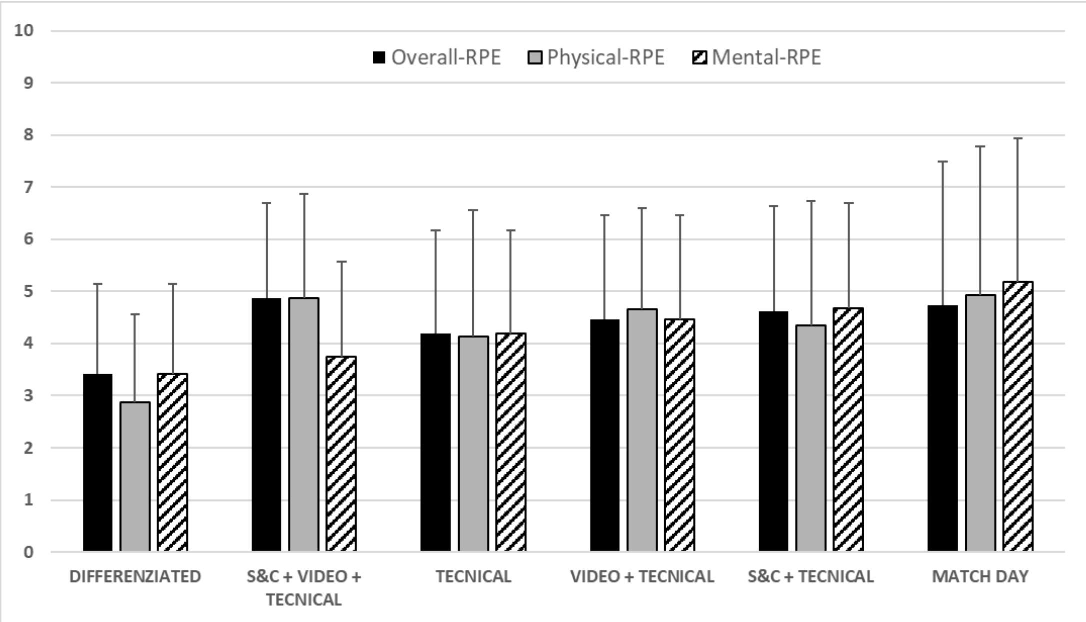


Figure 28. *Training type performed by the volleyball team and the respective differential rating of perceived Mental, Physical and Overall exertion. S&C = strength and conditioning training session. All data are presented as mean and standard deviations.*

It is notable the trend of different loads in the two soccer teams during a typical week. In particular, it can be appreciated how the physical load decreases during the week, in contrast to the mental load, which increases as the competition approaches. Nevertheless, the contribution of physical effort on overall effort is predominant on match day, while mental load is the lowest scores in game day. Furthermore, by performing the stepwise regression analysis for each type of training session carried out by the soccer players and by the volleyball players who participated in this study, it is possible to appreciate the different contribution on the total effort of the two physical and mental components of loads. Regarding the two soccer teams a different stepwise regression analysis was run per each training type. A significant regression equation was found (F(2,96) = 465.557 and p<.001), with an R^2 of 0.91 for the recovery training session (M-5). Participants' predicted O-RPE is equal to 0.006 + 0.775 * P-RPE + 0.304 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). Moreover, a significant regression equation was found (F(2,138) = 435.764 and p<.001), with an R^2 of 0.86 for the strength and conditioning plus tactical training session (M-4). Participants' predicted O-RPE is equal to 0.690 + 0.601 * P-RPE + 0.281 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). A significant regression equation was also found (F(2,133) = 213.346 and p<.001), with an R^2 of 0.76 for the small-sided games conditioning training session (M-3). Participants' predicted O-RPE is equal to 0.621 + 0.727 * P-RPE + 0.175 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). Furthermore, a significant regression equation was found (F(2,114) = 208.041 and p<.001), with an R^2 of 0.78 for the speed plus tactical training session (M-2). Participants' predicted O-RPE is equal to 0.355 + 0.721 * P-RPE + 0.209 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). In addition, a significant regression equation was found (F(2,136) = 310.612 and p<.001), with an R^2 of 0.82 for the agility and reaction plus tactical team-run training session (M-1). Participants' predicted O-RPE is equal to 0.497 + 0.727 * P-RPE + 0.125 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). Finally, a significant regression equation was also found (F(1, 73) = 1485.061 and p<.001), with an R^2 of 0.95 for the match day (MATCH DAY). Participants' predicted O-RPE is equal to 0.583 + 0.925 * P-RPE, where P-RPE is measured in arbitrary units (a.u.), and where the M-RPE does not weight on the overall-RPE because is not present in the equation.

Regarding the two volleyball teams a different stepwise regression analysis was also run per each training type. Because there were only few (<10) differentiated training session and strength and conditioning plus technical work and plus video use training sessions, they were excluded from the following analysis. A significant regression equation was found ($F(2,105) = 213.100$ and $p<.001$), with an R^2 of 0.80 for the technical training session (TECHNICAL). Participants' predicted O-RPE is equal to 0.442 + 0.622 * M-RPE + 0.277 * P-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). A significant regression equation was also found ($F(2,118) = 137.982$ and $p<.001$), with an R^2 of 0.70 for the strength and conditioning plus technical training session (S&C + TECHNICAL). Participants' predicted O-RPE is equal to 0.774 + 0.447 * M-RPE + 0.405 * P-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). Moreover, a significant regression equation was found ($F(2,32) = 4.895 \times 10^{32}$ and $p<.001$), with an R^2 of 1 for the video plus technical training session (VIDEO + TECHNICAL). Participants' predicted O-RPE is equal to 1 * M-RPE + 1.252×10^{-16} * P-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). Finally, a significant regression equation was also found ($F(2,77) = 205.577$ and $p<.001$), with an R^2 of 0.84 for the match day (MATCH DAY). Participants' predicted O-RPE is equal to -0.187 + 0.507 * P-RPE + 0.466 * M-RPE, where both M-RPE and P-RPE are measured in arbitrary units (a.u.). All the percentage of contributions of the mental and physical effort components are depicted in Figure 29, Figure 30 and in Figure 31.

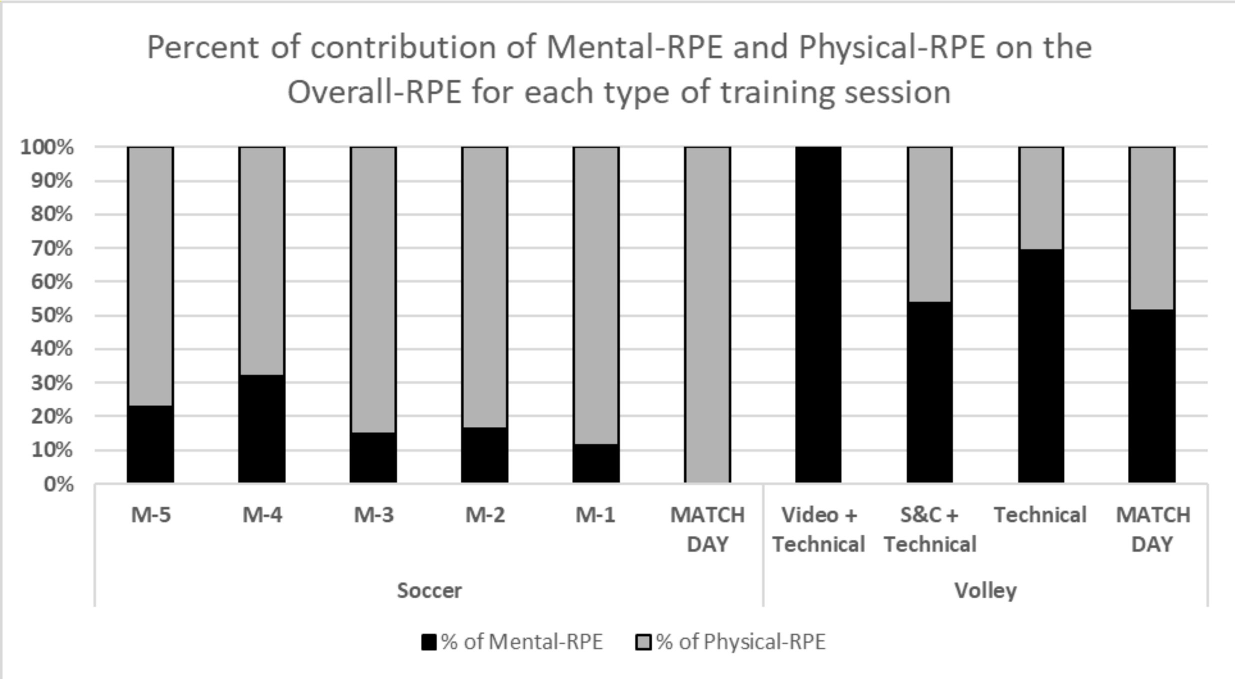


Figure 29. *Clustered Stacked Column chart representing the percent of contribution of Mental-RPE and Physical-RPE on the Overall-RPE for each type of training session and competitions performed by the soccer (left) and for volleyball (right) teams. All data are presented as percentage and thus without units of measurement.*

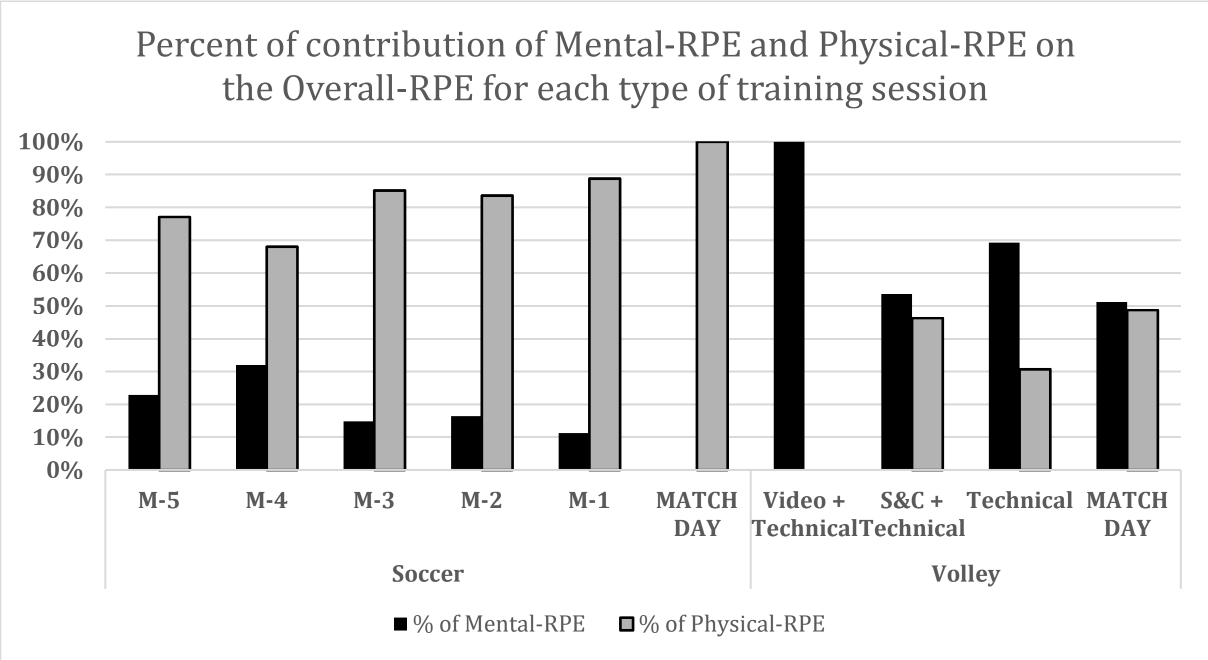


Figure 30. *Grouped Bar plot representing the percent of contribution of Mental-RPE and Physical-RPE on the Overall-RPE for each type of training session and competitions performed by the soccer (left) and for volleyball teams (right). All data are presented as percentage and thus without units of measurement.*

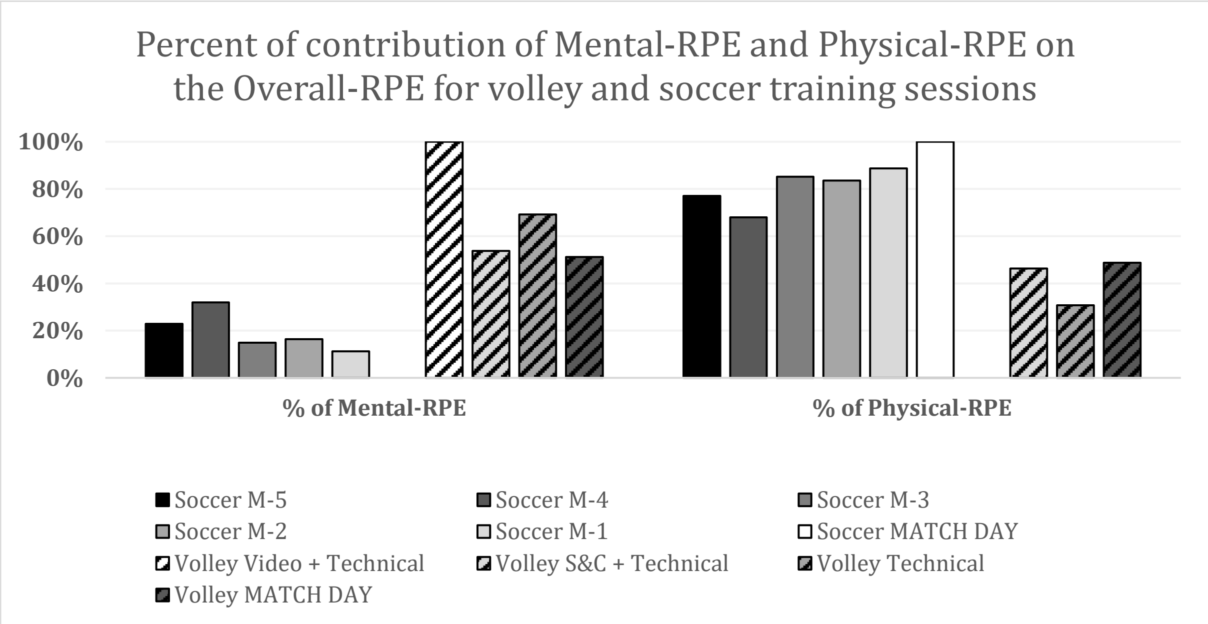


Figure 31. *Grouped Bar plot representing the percent of contribution of Mental-RPE (left) and Physical-RPE (right) on the Overall-RPE for each type of training session and competitions performed by the soccer (grayscale solid color filling) and for volleyball teams (grayscale oblique bar pattern filling). All data are presented as percentage and thus without units of measurement.*

In addition, Figure 32 details the trend of the two contributions as a function of the training days of the week for the two soccer teams involved in the present research.

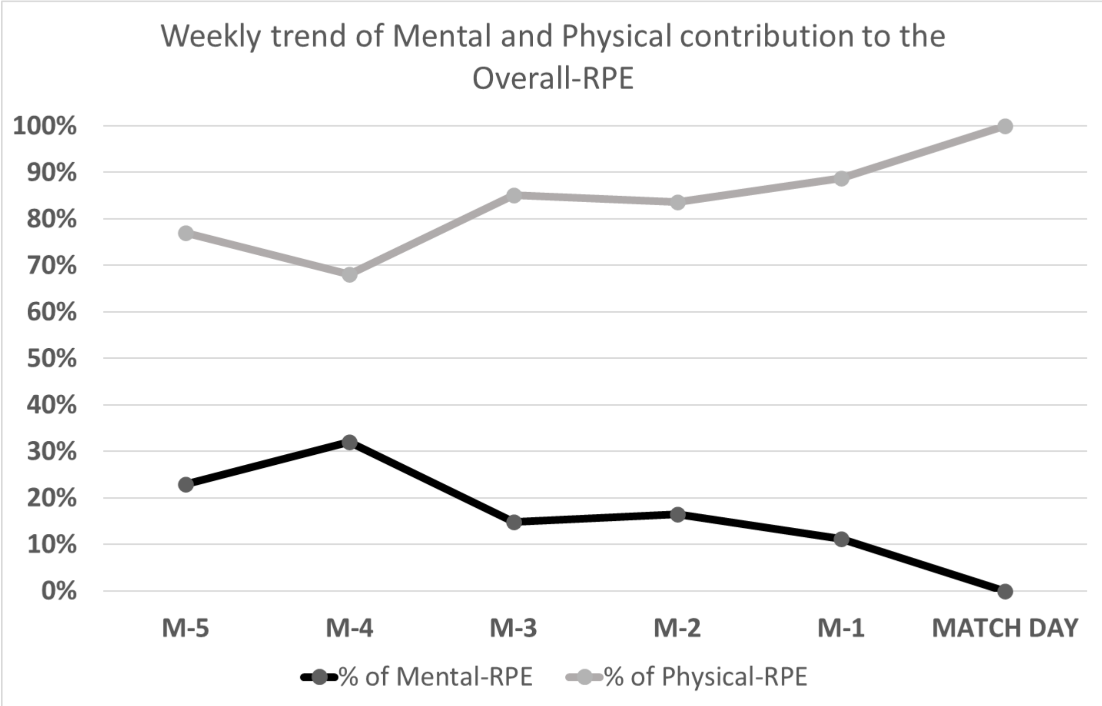


Figure 32. *Trend of the Mental and the Physical contributions to the Overall-RPE as a function of the training days of the week for the two soccer teams involved in the present research. All data are presented as percentage and thus without units of measurement.*

The relationships between the results of the daily Wellness questionnaires and the subjective variables of the differential perceived effort are summarized in the following tables for the two soccer teams separately, for the two volleyball teams together and all the teams together in Table 13, in Table 14, in Table 15, and in Table 16 respectively.

Regarding the Serie D soccer team, a negative effect size below -0.2 was found in the relationship between the Mental-RPE, the Physical-RPE and the Overall-RPE and between the fatigue items (-0.28 - -0.34), the stress items (-0.26 - -0.43) of the wellness questionnaire and the total wellness index (-0.21 - -0.37). The highest value was recorded for the relationships with the Mental-

RPE score for all the three comparisons. The total wellness index shows medium relationship between 0.34 and 0.37 with the training load of the day before. A score between 0.41 and 0.53 was found in the relationship between the stress items of the wellness questionnaires and the day minus one training loads. Higher effect size values were found between the fatigue items and the training load of the day before (0.52 – 0.61). Furthermore, a small negative relationship (-0.19 – -0.023) was detected between the sleep items of the wellness questionnaire and the weekly training lo ad. All effect sizes are detailed in Table 13.

X	FATIGUE	SLEEP	DOMS	STRESS	MOOD	INDEX
ORPE	-0,28	-0,11	-0,04	-0,26	-0,01	-0,23
PRPE	-0,26	-0,08	-0,04	-0,27	0,05	-0,21
MRPE	-0,34	-0,20	-0,08	-0,43	0,05	-0,37
TL	-0,17	-0,07	-0,06	-0,15	0,01	-0,14
TLP	-0,16	-0,03	-0,06	-0,16	0,07	-0,11
TLM	-0,22	-0,14	-0,11	-0,32	0,07	-0,27
TL-1	0,61	0,16	0,03	0,53	0,07	0,37
TLP-1	0,60	0,15	0,03	0,52	0,10	0,36
TLM-1	0,52	0,12	0,00	0,41	0,13	0,34
TL-2	0,02	0,09	-0,04	0,18	-0,11	0,04
TLP-2	0,04	0,06	-0,04	0,18	-0,08	0,05
TLM-2	-0,15	0,12	-0,04	0,04	-0,10	-0,03
WTL	0,07	-0,19	-0,08	0,13	-0,13	-0,06
WTLP	0,05	-0,23	-0,13	0,16	-0,10	-0,07
WTLM	0,02	-0,20	-0,18	0,01	-0,15	-0,15

Table 13. *Relationships between the wellness scores in the columns, and between the scores of the differential perceived exertion scales in rows, for the Serie D soccer team involved in the present research. ORPE = Overall-RPE; PRPE = Physical-RPE; MRPE = Mental-RPE; TL = Training Load; TLP = Physical Training Load; TLM = Mental Training Load; -1 = of the day before; -2 = of the 2 days before; W = weekly;*

Regarding the Serie C soccer team, a negative medium effect size between -0.33 and -0.56 was detected between the three RPE scores and the fatigue items (-0.44 - -0.56), the DOMS items (-0.40 - -0.54), the of the wellness questionnaire and the total wellness index (-0.33 - -0.38). In particular, the lowest value was recorded for the relationships with the Mental-RPE score in all the three comparisons. Consequently, training load variable show a negative relationships with the fatigue items (-0.22 - -0.57) and with the DOMS items (-0.29 - -0.54) of the wellness questionnaire. Mental-RPE training load has the lowest values in all these last comparisons. The training load of two days before show a relationship with the DOMS items (-0.29 - -0.54) of the wellness questionnaire. In addition, Mental-RPE training load of two days before also show a relationship with the fatigue items (0.25) and with the sleep items (0.20) of the wellness questionnaire. The sleep item has also shown a relationship with the weekly training load (-0.28 - -0.31). All effect sizes are detailed in Table 14.

X	FATIGUE	SLEEP	DOMS	STRESS	MOOD	INDEX
ORPE	-0,56	0,07	-0,54	-0,26	-0,12	-0,38
PRPE	-0,56	0,09	-0,50	-0,24	0,02	-0,33
MRPE	-0,44	0,02	-0,40	-0,15	-0,18	-0,33
TL	-0,57	0,06	-0,54	-0,26	-0,10	-0,38
TLP	-0,40	0,12	-0,46	-0,21	0,12	-0,22
TLM	-0,22	-0,01	-0,29	-0,02	-0,14	-0,19
TL-1	-0,07	-0,06	0,01	-0,11	-0,06	-0,08
TLP-1	-0,08	-0,04	0,00	-0,08	-0,02	-0,05
TLM-1	-0,06	-0,01	-0,06	0,02	-0,07	-0,05
TL-2	0,11	0,13	0,22	-0,10	-0,14	0,06
TLP-2	0,07	0,14	0,21	-0,07	-0,06	0,08
TLM-2	0,25	0,20	0,28	-0,03	-0,13	0,18
WTL	-0,02	0,30	-0,06	-0,02	0,15	0,11
WTLP	-0,04	0,28	-0,08	-0,01	0,18	0,11
WTLM	-0,05	0,31	-0,07	0,09	0,18	0,14

Table 14. *Relationships between the wellness scores in the columns, and between the scores of the differential perceived exertion scales in rows, for the Serie C soccer team involved in the present research. ORPE = Overall-RPE; PRPE = Physical-RPE; MRPE = Mental-RPE; TL = Training Load; TLP = Physical Training Load; TLM = Mental Training Load; -1 = of the day before; -2 = of the 2 days before; W = weekly;*

Regarding the two élite volleyball teams an effect size above 0.2 was found in the relationship between the weekly training load and the stress items of the questionnaires (0.24 – 0.27). Mental-RPE, the Physical-RPE and the Overall-RPE have an effect size score between 0.24 and 0.30 compared to the fatigue items of the wellness score for the Physical-RPE and for the Overall-RPE scores, and compared to the DOMS score only for the Physical-RPE scores, and between the stress items of the wellness questionnaire for all the three RPE-based scales, and between the total wellness index score for the Physical-RPE only. Consequently, same relationships were detected between the corresponding training load variable and the items of the wellness questionnaire.

The training loads of the day before shows an effect size score between 0.33 and 0.37 for all the three RPE-based scales and the DOMS items of the wellness questionnaires, and a score between 0.20 and 0.24 for all the three RPE-based scales and the wellness index of the questionnaires. A score between 0.24 and 0.27 was also found between the stress items of the wellness questionnaires and the weekly training loads obtained from all the three RPE-based scores. All effect sizes are detailed in Table 15.

X	FATIGUE	SLEEP	DOMS	STRESS	MOOD	INDEX
ORPE	0,20919	0,01807	0,10891	0,28275	-0,17820	0,17979
PRPE	0,27344	0,09181	0,25940	0,30443	-0,02514	0,30312
MRPE	0,12793	-0,03409	0,03127	0,24063	-0,20841	0,09309
TL	0,26389	0,06482	0,14554	0,27132	-0,09328	0,23227
TLP	0,31643	0,13333	0,28125	0,29258	0,02760	0,34152
TLM	0,18116	0,01174	0,06124	0,23712	-0,14015	0,14512
TL-1	0,21153	0,15283	0,37482	0,15326	0,02986	0,24852
TLP-1	0,17149	0,12054	0,35022	0,13824	-0,01882	0,20613
TLM-1	0,14960	0,12724	0,33823	0,13283	-0,00218	0,20794
TL-2	-0,00595	0,02188	0,06106	0,06462	0,12464	0,07007
TLP-2	-0,03314	0,05580	0,00192	0,00987	0,15573	0,05056
TLM-2	0,00625	0,02719	0,04548	0,02851	0,08912	0,05102
WTL	0,13407	0,09291	0,15232	0,26655	-0,09934	0,14036
WTLP	0,10027	0,08165	0,15006	0,24836	-0,09957	0,12043
WTLM	0,13059	0,10072	0,12640	0,27823	-0,09083	0,14100

Table 15. *Relationships between the wellness scores in the columns, and between the scores of the differential perceived exertion scales in rows, for the two volleyball teams involved in the present research. ORPE = Overall-RPE; PRPE = Physical-RPE; MRPE = Mental-RPE; TL = Training Load; TLP = Physical Training Load; TLM = Mental Training Load; -1 = of the day before; -2 = of the 2 days before; W = weekly;*

Aggregating the data from all four teams involved in the present study the effect size scores result lower in all the comparisons. A positive relationship with an effect size between 0.20 and 0.27 was found between the three training loads of the day before and the fatigue items, the stress items (0.21 – 0.22) of the wellness questionnaire and the total wellness index (0.01 – 0.22). All other effect sizes were found to be below 0.2 for all the comparison. All effect sizes are detailed in Table BBB.

X	FATIGUE	SLEEP	DOMS	STRESS	MOOD	INDEX
ORPE	-0,12	-0,01	-0,10	0,01	-0,05	-0,07
PRPE	-0,09	0,03	-0,04	0,02	0,04	0,00
MRPE	-0,14	-0,07	-0,13	-0,03	-0,07	-0,13
TL	-0,06	0,02	-0,11	0,04	-0,02	-0,03
TLP	0,02	0,07	-0,01	0,06	0,08	0,07
TLM	-0,01	-0,04	-0,09	0,05	-0,04	-0,02
TL-1	0,27	0,10	0,19	0,22	0,03	0,22
TLP-1	0,25	0,08	0,17	0,22	0,02	0,20
TLM-1	0,22	0,10	0,16	0,21	0,04	0,21
TL-2	0,00	0,06	0,07	0,05	-0,03	0,04
TLP-2	-0,01	0,06	0,04	0,03	0,01	0,04
TLM-2	0,01	0,09	0,07	0,04	0,01	0,06
WTL	0,08	0,11	0,05	0,17	-0,02	0,11
WTLP	0,05	0,09	0,03	0,16	-0,01	0,09
WTLM	0,07	0,10	0,03	0,19	-0,03	0,10

Table 16. *Relationships between the wellness scores in the columns, and between the scores of the differential perceived exertion scales in rows, for all the four teams involved in the present research. ORPE = Overall-RPE; PRPE = Physical-RPE; MRPE = Mental-RPE; TL = Training Load; TLP = Physical Training Load; TLM = Mental Training Load; -1 = of the day before; -2 = of the 2 days before; W = weekly;*

The relationships between the results of the athletes Mood State questionnaires (BRUMS) filled before and after the monitored period per each team and the subjective variables of the differential perceived effort scales are summarized in the following Table 17. Confidence Intervals of the linear fitted model built to study the relationship between the Training Loads variables and the BRUMS questionnaire differential (PRE vs POST) are reported for the lower 2.5% and for the upper 97.5% confidence limits, respectively.

VARIABLES	**Confidence Intervals**	
	2.5%	**97.5%**
Training Load (Overall-RPE * time)	-84.59144	120.8177
Mental Training Load (Mental-RPE * time)	-68.05901	131.8823
Physical Training Load (Physical-RPE * time)	-94.42948	112.0268
Total Training Load (Σ Overall-RPE TL + Mental-RPE TL + Physical-RPE TL	-242.1576	359.8045

Table 17. Confidence Intervals of the linear fitted model representing the relationship between the Training Loads variables (rows) and the differential score of the BRUMS questionnaire between PRE and POST period. The lower limit was set at 2.5% and the upper limit was set at 97.5% of the confidence limits, respectively. Training Loads variables are obtained in accord with the session-RPE methodology, or rather multiplying the RPE scales scores for the total duration of the session.

DISCUSSION

The main purpose of this field study was to study the relationships between differential training loads and some indices of fitness level and mood employed with professional athletes, during the final playoff phase of a competition period. Negative relationships were found in both soccer teams between the three RPE scales and the fatigue items, the stress items, and the wellness index of the questionnaire. Controversially, in one of the soccer team a relation was also found with the DOMS items. These differences may be due to the differences in physical demands of the respective championships. In the same team, a relationship was found with the sleep items of the wellness questionnaire and the weekly training load. Between the two soccer teams, some differences were also found in the relationships with the training loads of the day before and the training loads of two days before. The team that reported the highest relationships with the DOMS items of the wellness questionnaire also had the most significant relationships with the training load variables of two days before respect with the other training load variables in all the comparisons. This could confirm the higher physical demand for of the players in the respective championship.

Regarding the two volleyball teams, the most interesting relationships emerged from this study are those between the DOMS items, and the wellness index of the questionnaire with the training load of the day before variables, and between the weekly training load variables and the stress items of the questionnaire. The RPE scales and the training load variables shown several relationships with the items of the wellness questionnaire, maintaining the interesting pattern that the Mental-RPE measures results to have the weak relationships. Analyzing the aggregate data of the four teams does not allow detecting any significant relationships. The diversity of the technical and physical demands of the sports involved in the present research and the differences between the athletes' performance levels do not allow to detect any relationships between the questionnaire variables and the training loads variables.

These results support the hypothesis of the usefulness of differentiating training load experienced by the athletes in training and in competition using the Physical-RPE and the Mental-RPE. Giving this evidence the first hypothesis of the present investigation was confirmed.

A secondary hypothesis of the present investigation was that an accumulation of mental stress by athletes during the play-off part of the season resulted in lower mood state detected by the BRUMS questionnaire and by the wellness questionnaire. Regarding the BRUMS questionnaire, no significant relationship was found with any of the training loads variables measured in this research. Similarly, the mood items of the daily wellness questionnaire used during the player monitoring period revealed no relationships (ES < 0.2) with any of the differential training load variables in any of the four teams and with the aggregate data. Giving this evidence the secondary hypothesis of the present investigation was rejected.

Therefore, a secondary aim of this study was to run a descriptive study with semi-professional athletes to analyze the usefulness of the use of the new RPE differential scales respect to the use of the classic Overall-RPE in training monitoring athletes. Regarding the two soccer teams the Physical-RPE scores are in line with the Overall-RPE scores in all the training session type and in the match day. The results of the present research shown that the Overall-RPE scores are higher at the beginning of the training week and progressively decay as the match approach. On the contrary the contribution of the Physical-RPE to the Overall-RPE increase during the week. Instead, the contribution of the Mental-RPE to the Overall-RPE decrease during the week and is zero during the match day. The Mental-RPE scores are stationary during the week. Mental-RPE score are lower in the first two days of the week and show similar scores respect to the Overall-RPE and to the Physical-RPE scores in the last training session of the week. These results are in accord with the findings of previous study by Impellizzeri and colleagues and by Perri and colleagues (Impellizzeri et al., 2004; Perri et al., 2021). Regarding the two volleyball teams, the scores most similar to the match day were recorded in the strength and conditioning plus technical plus video-based training sessions. The proportion of contribution of mental effort and physical effort most similar to the match day, about 50% each, was detected in the strength and conditioning plus technical training session.

Similar to study one of this thesis, through a regression analysis, the different contribution of physical effort and of the mental effort on the overall effort for each type of training performed by the soccer teams and by the volleyball teams was calculated. The results of these analysis are in accord with the results of the first study of this thesis. The physical effort perceived by the athletes and measured by the Physical-RPE contribute more to the overall-RPE respect to the Mental effort measured by the Mental-RPE in most of the training session typology analyzed in the present study.

During the monitoring period under consideration, no performance tests were administrated. This represents a limitation in the present research. Furthermore, other training loads were not measured as in example using GPS, heartrate monitor or accelerometers. In addition, match results were not included in the analyses. Further research using these variables are strongly recommended. Furthermore, in addition to the mood state of the athletes measured by questionnaires of questionable validity, it would be interesting to add a performance test to better evaluate both the psychological and the physiological state of athletes.

Training Loads can be monitored by differentiating physical and mental loads in a similar way to the methodology used with session RPE. Also, in light of the lack of demonstrated validity of the daily measures that claim to measure the psychological components of the training loads to which athletes are exposed during the training process, having an athlete-friendly measure such as the RPE-based scales object of this research promises to represent a useful tool. This simple instrument allowed coaches and practitioners to monitoring daily any alterations in the psychological states of the athlete experienced during training and competitions. To measure the overall psychological load on athletes, in accord with Mellalieu and colleagues it is important to integrate the performance psychological load with a measure the other two sources of psychological load: the personal and the organization contextual factors.

GENERAL DISCUSSION

Aims and development of the scale

It is common practice in high-level sports to focus primarily on physical loads when monitoring the workloads to which athletes are exposed. However, it is necessary to consider all sources that may represent stress to athletes. Recently, psychological loads have assumed greater importance in both field practice and in research. Some authors tried to identify the sources of psychological load in athletes. These can arise from personal aspects, from organizational aspects, or coming directly from the experience of training or competition (Mellalieu et al., 2021). Several attempts have been made trying to measure these components (Garbutt 2017; Bourdon et al., 2017; Kellmann et al., 2018; Meeusen et al., 2013; Proost et al., 2022; Schwellnus et al., 2016). Regarding stress that does not originate from the physical demands of training, several attempts have been made to identify suitable instruments and variables (Fletcher et al., 2012; Mellalieu et al., 2009; Neil et al., 2011). Frequently, psychological load has been identified using the term cognitive load, and referred to the technical-tactical aspects of the sport discipline practiced (McLaren et al., 2017; Mullen et al., 2021). In alternatives the term mental load referring to the whole cognitive, attentional, psychological, and emotional aspects experienced by athletes was adopted with athletes. Number of questionnaires and different scales have been created to measure mental load even though they have poor validity, or they were not born for this purpose (Díaz-García et al., 2021; Filho et al., 2024; Filipas et al., 2021; García-Calvo et al., 2021; Ghanbary Sartang et al., 2016; Hart, 2006; Hart & Staveland, 1988; Said et al., 2020; Staiano et al., 2023, 2022; Thompson et al., 2019). However, none of the attempts made by the researchers completely met the requirement in term of validity and reliability, or in term of specificity and feasibility.

Given this evidence, the main purpose of this dissertation was to propose an instrument for subjective measurement of athletes' psychological load experienced during training and competitions. The CR10 scale adapted from Foster was used as effort rating scales (Foster et al., 2001). The questions associated with each scale were created by merging questions used in the differential scales previously suggested by Borg and including terms frequently used in the scientific literature to describe cognitive demand during exercise, for the Physical-RPE and for the Mental-RPE scale, respectively. Subsequently, we start the validation process of two new differential RPE scales, the Physical-RPE and the Mental-RPE respectively. In the present multiple study research, more than two hundred athletes from amateur to international level and nine semiprofessional and professional teams have been involved. It has been hypothesized that these RPE scales are valid and reliable and easy for coaches and athletes to use and understand. It has also been hypothesized that differentiating the mental from the physical effort experienced by athletes can help coaches and practitioners by providing additional information compared to the tools traditionally used in monitoring athletes' workloads and players performance levels during training and competitions.

VALIDITY AND RELIABILITY

Criterion Validity

The new scales proposed in the present research showed a good criterion validity compared to the criterion measure. Study 1 was conducted with more than two hundred athletes of amateur to international level. A training session of their routine of individual and team sports athletes was compared. The full range of intensity scales used to assess differential efforts during exercise was reported by the athletes in the present study. High correlations were found between subjects for both scales. A correlation of r=0.804 and r=0.845 was found for the Mental-RPE and for the Physical-RPE, respectively. The new differential RPE scales are able to measure the physical and mental demands of training likewise of the NASA-TLX questionnaire. High correlations were found also within subjects in study two and in study four of the present research. A correlation of r=0.647 and r=0.795 was found for the Mental-RPE and for the Physical-RPE, respectively in study two. A correlation of r=0.903 and r=0.704 was found for the Mental-RPE and for the Physical-RPE, respectively in study four. Two semi-professional rugby and soccer teams were involved in study two. The players were monitored and answered questionnaires for three and four weeks, respectively. In study four, responses were obtained from thirty subjects who performed four short workouts in a single laboratory visit. The two differential RPE scales have been shown to be valid in measuring the physical and mental demands in both laboratory and field settings with trained man and female and with male semi-professional team sports players, respectively. Both scales have good criterion validity both within and between subjects, so even considering the individual variabilities of athletes both the Mental-RPE and the Physical-RPE scales proposed in this research are capable of measuring the different types of effort experienced by athletes in training. Especially high-level athletes who had more experience using the scales reported to coaches a greater ease in understanding the RPE-based scales than the unusual NAS-TLX questionnaire design confirming one of the assumptions of the present research.

Discriminant Validity

The discriminant validity of the differential RPE scales was shown to be good in both laboratory and field settings. In a single laboratory visit, four different training conditions were tested in a cross-counterbalanced design study in which both physical and cognitive load were modulated through different running speeds and with the presence of a free recall memory test. In the first two experimental conditions with higher physical intensity, both the Overall-RPE and the Physical-RPE show higher values ($p < 0.001$) than the two conditions in which physical intensity demand was lower. Mental-RPE scores were higher ($p < 0.001$) than in the two conditions in which the cognitive task was not present indicating that this scale can differentiate different types of mental load. In addition, non-significant main effect was detected for the Mental-RPE scale. This further support the use of a differentiated RPE scales in case it is necessary to quantify the mental load of a training session.

Two different mental and physical demanding training sessions of a rugby union and a soccer team were compared. Regarding the rugby union team, comparisons between the two training sessions examined show that the Physical-RPM scale was able to discriminate between two different physical demand training sessions ($p = 0.008$). Similar results are obtained with the soccer team monitored for four weeks. The Mental-RPE scale was able to detect differences between two different mentally demanding training sessions ($p = 0.00192$). The discriminant validity assessed in the laboratory in study 4 and the results of the ecological field study 2 both supports the discriminant validity of the proposed RPE differential scales. The scales are able to measure the different physical and mental perceived exertion of athletes during different types of exercise. The discriminant validity of the two new differential-RPE scales proposed in this research has to be consider good because has been assessed in a laboratory setting with trained participants and in the field setting with semi-professional athletes.

Reliability

A field reliability study with professional and semiprofessional athletes was designed. To test the reliability of the two scales proposed in the present research two identical training protocols were administered. Two professional handball teams and two semi-professional volleyball teams were involved, and two conditioning training sessions were monitored seven days apart. Workloads, training duration, and all contextual factors were the same between the two training sessions. After each of the two sessions performed, players filled out questionnaires with the differential-RPE scales and the NASA-TLX without knowing that the purpose was to assess agreement between the two measures. Players rated the two training sessions in agreement with both the Mental-RPE (ICC = 0.752) and the Physical-RPE (ICC = 0.647) scale. The reliability of the scales was found to be good and moderate for the Mental-RPE and the Physical-RPE respectively. These results were obtained through an ecological field study with professional and semi-professional players of different male and female team sports. Players reported similar scores in both Mental-RPE and Physical-RPE scales in both the two training sessions monitored for the present study. Correlations between the rated scores indicates a good reliability of the two differential RPE scales proposed in the present research.

OTHER FINDINGS

Contribution of physical and mental load to overall load

In study 1, more than 200 athletes of amateur to international level who performed workouts of different types were tested. The values reported by the athletes covered all the intensity levels in all the scales used in the present research. A regression analysis was run to estimate the contribution of the physical and mental efforts on the Overall-RPE. A contribution of 36% of the Mental-RPE and of the 60% of the Physical-RPE was calculated ($F(2,199) = 316.207$; $p<.001$; $R2 = 0.76$). In study 5 of this thesis, the different contribution of physical effort and of the mental effort on the overall effort for each type of training performed by the soccer teams and by the volleyball teams was calculated. The main findings were that in the soccer teams the Overall-RPE scores were higher at the beginning of the training week and progressively decayed as the match approached. On the contrary, the contribution of the Physical-RPE to the Overall-RPE increased during the week. Instead, the contribution of the Mental-RPE to the Overall-RPE decreases during the week and is absent during the match day. The results of this analysis are in accord with the results of the study 1 of this thesis. The physical effort perceived by the athletes and measured by the Physical-RPE contribute more to the overall-RPE respect to the Mental effort measured by the Mental-RPE in the training session analyzed in the present study. Finally, this last analysis makes it possible to highlight how the different contribution of the physical component to the overall effort perceived by athletes suggests that it is appropriate to measure separately the mental and the physical component experienced by athletes during training and competition.

Correlates of physical and mental load

Study 5 investigated the relationships between differential RPE training loads and athletes' mood assessed through two different questionnaires. In particular, the Mental-RPE variable, and consequently the other derived training load variables, show different relationships from the other RPE-based scales with the items of the daily athlete fitness questionnaire used in the present study. Negative relationships were found in both soccer teams between the three RPE scales and the fatigue items, the stress items, and the wellness index of the questionnaire as expected. These results are in accord with the current literature. The DOMS item of the wellness questionnaire shows some differences in the relationships with training load variables in one of the two teams probably due to the different physical demand of the championship level performed. Same relationships were found in both volleyball teams between the three RPE scales and the fatigue items, the stress items, and the wellness index of the wellness questionnaire respectively. Moreover, the DOMS item of the wellness questionnaire shows relationships with weekly training load variables, training loads of the day before, and with the wellness index variables. Mental-RPE scores have weak relationships in most of the comparisons performed in the present research, compared to the other RPE scales. Regarding the mood of the athletes, no significant relationships were found between the two questionnaires and the

RPE scales used in the present research. The differential RPE scale of Mental-RPE showed different relationships with all the variables of the questionnaires used in the present research, compared to the Physical-RPE and classical Overall-RPE. The use of the differential RPE scales as a tool for monitoring training loads in training and competition is suggested to better understand the relationship between fitness status and performance levels of players.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Some limitations were found by conducting the present research. The main limitation was the scales were designed for athletes to be used in training and competition and therefore they needed a field settings validation, before performing some assessments in a laboratory setting. Instead, in this case was first assessed the athletes' ability to use the scales and after how the scales performed in a laboratory setting where physical load and cognitive load were manipulated and controlled. The present multiple studies research projects do not represent a complete validation of the scales. Longer investigations of multiple weeks of training and at different times of the season are needed to further examine the usefulness of these instruments. This limitation is partly due to the length of the doctoral course that this research was conducted for. In addition, monitoring psychological load can be very useful at particular times in the athlete's life such as transition phases i.e., transition from junior to senior or retirement at the end of career, or long-time injured athletes. Further investigations, in these particularly relevant periods of athlete’s carriers are strongly recommended. Therefore, further research is required to assess the discriminant validity of these two new scales in both laboratory and field training with more varied demands, as in example physical and technical-tactical training sessions or manipulating cognitive and physical load.

CONCLUSION AND PRACTICAL APPLICATION

Although various instruments exist for measuring the physical and mental demands of training, the NASA-TLX questionnaire was used in this research as a criterion measure because its validity and its wide in the literature. However, this tool may not be so athletes-friendly compared to other instruments commonly used by athletes. The use of differentiated RPE scales would seem to be the least difficult solution for athletes to quickly understand coaches' questions and provide reliable answers. Compared with previous attempts to discriminate a load not resulting from the physical stress of training and competitions in athletes, the results of the studies of this research are encouraging. The results of this research provide preliminary evidence of the potential employment of the new differential RPE scales in athletes management and training loads monitoring. The scales can be used on the field, with both individual and team sports, and with both men and women athletes. The new differential RPE scales were feasible within a field setting. The scales appear to be able to discriminate different types of loads, differentiating between the physical and the mental loads.

In conclusion, the two RPE-based scales used in the present research appear to be valid and reliable. These tools can be used on the field in various individual and team sports. The two RPE-based scales represent a valid tool for evaluating the psychological load to which athletes are exposed during both training and competition. Furthermore, these unidimensional scales could represent some versatile and well-understood tool for athletes to differentiate the load sources during training or competitions, separately identifying the physical load from the mental load perceived by athletes. In the future, it could become a tool to replace the overall RPE scale and integrate with new technology tools for monitoring athletes' training loads more holistically and accurately. Using the two differential RPE scales to monitor athletes could results a relevant tool in handling critical situations with athletes involving the psychological load athletes are exposed in training and competitions.

Conflict of interest

The authors have no conflict of interest to declare. No financial resources were used to carry out this research. The coaches and technical staff of the teams involved in this research cooperated voluntarily and without any remuneration. The results of the present study do not constitute an endorsement by the American College of Sports Medicine. All the results of the present study are presented clearly, honestly, and without any kind of fabrication, falsification, or inappropriate data manipulation. All practices carried out in this research were in accordance with the principles of research ethics and were strictly observed throughout the entire research process.

APPENDIXES

Appendix 1: Overall RPE scale:

Italian: Com’è stato il tuo allenamento?

English: How was your training?

VALORE:	DESCRITTORI:
0	Riposo
1	Molto, molto facile
2	Facile
3	Moderato
4	Abbastanza duro
5	Duro
6	.
7	Molto Duro
8	.
9	.
10	Massimale

Appendix 2: Physical RPE scale:

Italian: Per quanto riguarda lo sforzo muscolare e/o respiratorio richiesto, quanto è stato duro l'allenamento?

English: With respect to the muscular effort and/or breathing required, how hard was your workout?

VALORE:	DESCRITTORI:
0	Riposo
1	Molto, molto facile
2	Facile
3	Moderato
4	Abbastanza duro
5	Duro
6	.
7	Molto Duro
8	.
9	.
10	Massimale

Appendix 3: Mental RPE scale:

Italian: Per quanto riguarda l'attenzione, la concentrazione, la memoria, l'apprendimento, l'emozione e/o la motivazione richieste, quanto è stato duro l'allenamento?

English: With respect to the attention, focus, memory, learning, emotion and/or motivation required, how hard was your workout?

VALORE:	DESCRITTORI:
0	Riposo
1	Molto, molto facile
2	Facile
3	Moderato
4	Abbastanza duro
5	Duro
6	.
7	Molto Duro
8	.
9	.
10	Massimale

Appendix 4: NASA-TLX ITA

Richiesta mentale

Quanta attività mentale e percettiva era richiesta (es., pensare, decidere, calcolare, ricordare, osservare, cercare, ecc.)?
Il compito era facile o difficile, semplice o complesso, impegnativo o leggero?

1 **5** **10** **15** **20**

○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

Bassa	**Alta**
Compito facile, semplice, leggero	Compito difficile, complesso, impegnativo

Richiesta fisica

Quanta attività fisica era richiesta (es. spingere, tirare, girare, controllare, attivare, ecc,)?
Il compito era facile o impegnativo, lento o rapido, leggero o pesante, riposante o faticoso?

1 **5** **10** **15** **20**

○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

Bassa	**Alta**
Compito facile, lento, leggero, riposante	Compito impegnativo, rapido, pesante, faticoso

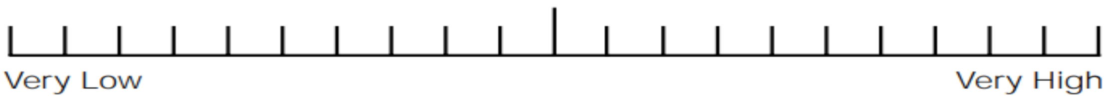
Obtained from: Bracco, F and Chiorri, C. Versione Italiana del NASA-TLX. F Bracco and C Chiorri" Versione Italiana del NASA-TLX, 2008.

Appendix 5: NASA-TLX ENG

The following questions deal with the workload that you experience in your job. Please put an ‘X’ on each of the following scales at the point that matches your overall experience of workload.

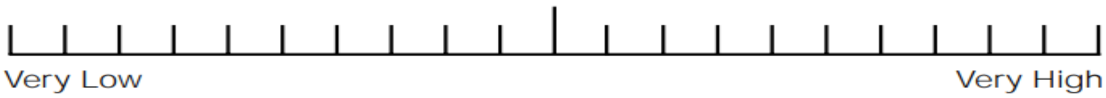
Mental demand.

How much mental activity is required to perform your job (thinking, deciding, calculating, remembering, looking, searching, etc…)?



Physical demand.

How much physical activity is required to perform your job (e.g., pushing, pulling, turning, controlling, activating, etc.)?



Otained from: Hart, SG and Staveland, LE. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In: Advances in Psychology (Vol. 52). Hancock, PA and Meshkati, N, eds. North-Holland, 1988. pp. 139–183

Appendix 6: The Brunnel Mood Scale – BRUMS (Italian Version, ITAMS)

BRUNEL MOOD SCALE (BRUMS) Data: ___ / ___ / ___ Ora: ___: ___

Di seguito vengono riportati alcuni aggettivi utilizzati per descrivere il proprio stato dell'umore. Leggi ciascun aggettivo con attenzione e cerchia la riposta che meglio descrive COME TI SENTI ADESSO, IN QUESTO MOMENTO. UTILIZZA LA SCALA DA 0 A 4 DESCRITTA QUI SOTTO. Per favore, accertati di rispondere ad ogni punto.

0 = per niente 1 = un po' 2 = abbastanza 3 = molto 4 = moltissimo

	0	1	2	3	4
1. Spaventato	☐	☐	☐	☐	☐
2. Vivace	☐	☐	☐	☐	☐
3. Confuso	☐	☐	☐	☐	☐
4. Esausto	☐	☐	☐	☐	☐
5. Depresso	☐	☐	☐	☐	☐
6. Scoraggiato	☐	☐	☐	☐	☐
7. Seccato	☐	☐	☐	☐	☐
8. Esaurito	☐	☐	☐	☐	☐
9. Scombussolato	☐	☐	☐	☐	☐

10. Indolente	☐	☐	☐	☐	☐
11. Amareggiato	☐	☐	☐	☐	☐
12. Infelice	☐	☐	☐	☐	☐
13. Ansioso	☐	☐	☐	☐	☐
14. Preoccupato	☐	☐	☐	☐	☐
15. Energico	☐	☐	☐	☐	☐
16. Triste	☐	☐	☐	☐	☐
17. Intontito	☐	☐	☐	☐	☐
18. Nervoso	☐	☐	☐	☐	☐
19 Arrabbiato	☐	☐	☐	☐	☐
20. Attivo	☐	☐	☐	☐	☐
21. Stanco	☐	☐	☐	☐	☐
22. Irascibile	☐	☐	☐	☐	☐
23. Vigile	☐	☐	☐	☐	☐
24. Incerto	☐	☐	☐	☐	☐

Otained from: Brandt, R, Herrero, D, Massetti, T, Crocetta, TB, Guarnieri, R, de Mello Monteiro, CB, et al. The Brunel mood scale rating in mental health for physically active and apparently healthy populations. Health 08: 125–132, 2016. And from: Quartiroli, A, Terry, PC, and Fogarty, GJ. Development and Initial Validation of the Italian Mood Scale (ITAMS) for Use in Sport and Exercise Contexts. Front Psychol 8: 1483, 2017.

Appendix 7: Wellness ITA: adattato da Hooper index e McLean

Descrivi come ti senti in questo momento (rispetto alle seguenti variabili)

FATICA	**Nessuna Fatica**				**Molto stanco**
QUALITÀ DEL SONNO	**Ottima**				**Pessima**
INDOLENZIMENTO MUSCOLARE	**Nessuno**				**Molto indolenzito**
STRESS	**Molto rilassato**				**Molto stressato**
STATO D'ANIMO	**Molto positivo**				**Molto negativo**

Appendix 8: Wellness ENG adattato da Hooper index e McLean

Please describe how you currently feel (according to the following items)

FATIGUE	**No fatigue**				**Very tired**
	○	○	○	○	○
SLEEP QUALITY	**Very good**				**Very bad**
	○	○	○	○	○
MUSCLE SORENESS	**None**				**Very sore**
	○	○	○	○	○
STRESS	**Very relaxed**				**Very stressed**
	○	○	○	○	○
MOOD	**Very positive**				**Very negative**
	○	○	○	○	○

Adapted from:

1) Hooper, SL and Mackinnon, LT. Monitoring overtraining in athletes.

Recommendations. *Sports Med* 20: 321–327, 1995.

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4) Campbell, PG, Stewart, IB, Sirotic, AC, Drovandi, C, Foy, BH, and Minett, GM. Analysing the predictive capacity and dose-response of wellness in load monitoring. *J Sports Sci* 39: 1339–1347, 2021.

Appendix: 9: Informed consent statements:

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

DIPARTIMENTO DI SCIENZE PER LA QUALITÀ DELLA VITA

Questionario allenamento

Durata 2 minuti

MODULO INFORMATIVO PER LA PARTECIPAZIONE

– CONSENSO INFORMATO –

Titolo, Responsabile progetto: Gentile Signora/Signore, Lei è invitata/o a prendere parte a una ricerca condotta nel quadro del progetto “VALIDAZIONE DI SCALE DI MONITORAGGIO DEL CARICO FISICO E MENTALE DOPO ALLENAMENTO" di cui è responsabile il Dipartimento di Scienze per la Qualità della Vita. Prima di decidere se partecipare è importante che abbia tutte le informazioni necessarie per aderire in modo consapevole e responsabile. Le chiediamo di leggere questo documento e di fare a chi le ha proposto questo studio tutte le domande che ritiene opportune.

Breve descrizione e Obiettivi: Il progetto di ricerca persegue l'obiettivo di validare l'uso di questionari per individuare le componenti fisiche e mentali di carico di lavoro percepito dopo un allenamento. Per raggiungere questo obiettivo, i ricercatori impegnati nel progetto raccoglieranno e analizzeranno i dati relativi ad alcuni questionari sulla percezione dello sforzo e del carico di lavoro prima e dopo l'allenamento.

Cosa comporta la partecipazione allo studio? La partecipazione al progetto di ricerca comporta esclusivamente la compilazione di un questionario basato su circa dieci domande chiuse in cui aggiungere talvolta poche parole di descrizione.

Benefici, disagi e/o rischi potenziali della partecipazione: La partecipazione allo studio è volontaria e gratuita. Per i partecipanti la collaborazione non comporta nessun tipo di rischio o disagio. I ricercatori si attendono informazioni inerenti alla validità e attendibilità delle risposte date mediante i questionari e in nessun modo valutano la qualità o i contenuti dell'allenamento.

Ritiro dallo studio: Lei ha il diritto di ritirare in qualsiasi momento il suo consenso alla partecipazione a questo studio, anche senza preavviso o motivazione specifica.

Restituzione: Lei ha diritto a richiedere informazioni sui risultati e sull'esito della ricerca.

Misure previste per tutelare l'anonimato: L'elaborazione dei dati raccolti sarà condotta in modo da eliminare qualsiasi riferimento che possa permettere di ricollegare singole affermazioni a una determinata persona. I risultati della ricerca saranno pubblicati in forma riassuntiva e in nessun caso eventuali brevi citazioni saranno riconducibili a singole persone o società sportive.

Contatti: Per qualsiasi informazione e chiarimento su questo studio o per qualsiasi necessità può rivolgersi al ricercatore Federico Nigro (federico.nigro2@unibo.it) che sarà a sua disposizione per ulteriori informazioni o chiarimenti.

○ **ACCONSENTO**

○ **NON ACCONSENTO**

Appendix 10: Invitation to participate in the project:

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

DIPARTIMENTO DI SCIENZE PER LA QUALITÀ DELLA VITA

PROGETTO DI RICERCA: "VALIDAZIONE DI SCALE DI MONITORAGGIO DEL CARICO FISICO E MENTALE DELL'ALLENAMENTO"

- MODULO INFORMATIVO PER LA PARTECIPAZIONE -

Titolo, Responsabile progetto: Gentile società sportiva, vi invitiamo a prendere parte a una ricerca condotta nel quadro del progetto "VALIDAZIONE DI SCALE DI MONITORAGGIO DEL CARICO FISICO E MENTALE DELL'ALLENAMENTO" di cui è responsabile il Dipartimento di Scienze per la Qualità della Vita. Prima di decidere se partecipare è importante che abbia tutte le informazioni necessarie per aderire in modo consapevole e responsabile. Le chiediamo di leggere questo documento e di fare a chi le ha proposto questo studio tutte le domande che ritiene opportune.

Breve descrizione e Obiettivi: Il progetto di ricerca persegue l'obiettivo di validare l'uso di questionari per individuare le componenti fisiche e mentali del carico di lavoro percepito dopo un allenamento. Per raggiungere questo obiettivo, i ricercatori impegnati nel progetto raccoglieranno e analizzeranno i dati relativi ad alcuni questionari sulla percezione dello sforzo e del carico di lavoro dopo l'allenamento.

Cosa comporta la partecipazione allo studio? La partecipazione al progetto di ricerca comporta esclusivamente la compilazione di un questionario a domande chiuse da parte dei giocatori maggiorenni, e di un breve diario di allenamento da parte dello staff allenatore.

Benefici, disagi e/o rischi potenziali della partecipazione: La partecipazione allo studio è volontaria e gratuita. Per i partecipanti la collaborazione non comporta nessun tipo di rischio o disagio. I ricercatori si attendono informazioni inerenti alla validità e attendibilità delle risposte date mediante i questionari e in nessun modo valutano la qualità o i contenuti dell'allenamento.

Ritiro dallo studio: Ha il diritto di ritirare in qualsiasi momento il suo consenso alla partecipazione a questo studio, anche senza preavviso o motivazione specifica.

Restituzione: Ha diritto a richiedere informazioni sui risultati e sull'esito della ricerca.

Misure previste per tutelare l'anonimato: L'elaborazione dei dati raccolti sarà condotta in modo da eliminare qualsiasi riferimento che possa permettere di collegare singole affermazioni a una determinata persona. I risultati della ricerca saranno pubblicati in forma riassuntiva e in nessun caso eventuali brevi citazioni saranno riconducibili a singole persone o società sportive.

Contatti: Per qualsiasi informazione e chiarimento su questo studio o per qualsiasi necessità può rivolgersi al ricercatore Federico Nigro (federico.nigro2@unibo.it) che sarà a vostra disposizione per ulteriori informazioni o chiarimenti.

Strumenti utilizzati: Esempio delle scale utilizzate per il monitoraggio dei carichi di lavoro: Si utilizzerà una versione opportunamente tradotta della scala della percezione dello sforzo

CR10 creata da Borg (Foster, C, Florhaug, JA, Franklin, J, Gottschall, L, Hrovatin, LA, Parker, S, et al. A new approach to monitoring exercise training. J Strength Cond Res 15: 109–115, 2001). La scala sarà presentata chiedendo in generale una valutazione su "com'è stato l'allenamento appena svolto?", e come sono stati percepiti il carico mentale e il carico fisico.

Inoltre, verranno utilizzate due voci del questionario NASA-TLX sul carico fisico e mentale dell'allenamento (Hart, SG and Staveland, LE. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In: Advances in Psychology (Vol. 52). Hancock, PA and Meshkati, N, eds. North-Holland, 1988. pp. 139–183; Hart, SG. Nasa-Task Load Index (NASA-TLX); 20 Years Later. Proc Hum Fact Ergon Soc Annu Meet 50: 904–908, 2006.).

Appendix 11: Checklist with inclusion criteria for laboratory study participants

Participant ID: **Data:**

Hai assunto medicinali oggi? Si / No

Presenti una qualche malattia o forma di infezione? Si / No

Sei infortunato? Si / No

Note:

Nelle **24 ore** precedenti allo studio:

Hai evitato esercizio fisico intenso/pesante? Si / No

Hai dormito almeno 7 ore? Si / No

Hai fatto uso di alcohol? Si / No

Hai bevuto la quantità raccomandata di acqua? Si / No

Note:

Nelle 12 **ore** precedenti allo studio:

Hai assunto caffeina? Si / No

Hai fumato? Si / No

Note:

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