THE RATING OF PERCEIVED CHALLENGE- THE RELATIONSHIP BETWEEN PLAYER AND COACH PERCEPTIONS OF RUGBY TRAINING

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List of Abbreviations

Abbreviation	Explanation
RPE	Rating of Perceived Exertion
RPC	Rating of Perceived Challenge
ROE	Rating of Observed Exertion
RIE	Rating of Intended Exertion
sRPE	Session Rating of Perceived Exertion
sRPC	Session Rating of Perceived Challenge
RPE-B	Rating of Perceived Exertion- Breathlessness
RPE-L	Rating of Perceived Exertion- Leg
RPE-T	Rating of Perceived Exertion- Technical
AU	Arbitrary Units
CR	Category Ratio

Abstract

Introduction: Monitoring training is a common practice in sport, however skill training is not periodised and monitored to the same extent as physical training. Furthermore, it is important that the coach's and player's understanding of the training load is alike to avoid maladaptation and to modify future training sessions. The first part of this thesis aims to synthesise research that investigates the relationship between coach RPE and player RPE by means of a systematic review. The second part is an original study that uses a technical skill measurement (rating of perceived challenge, RPC) and tests (i) the relationship between player and coach RPC, (ii) the relationship between player session rating of perceived exertion (sRPE) and RPC, and (iii) the differences between backs and forwards for sRPE and RPC, within gym and field-based training sessions.

Methods: For the systematic review, 4915 articles were retrieved from 4 databases using the following search terms: Train*) OR ('Training-Load') OR ('Load-monitoring') OR ('training-load-monitoring') AND ('Internal-load') OR ('subjective-ratings') OR ('perception-of-effort') OR ('perceived-exertion') OR ('perceived-stress') AND (Coach*) OR (Player*) OR (Player*). After duplicates were removed a total of 1591 articles were reviewed for inclusion. Studies that reported the relationship, association, difference or agreement between the player and coach were included in the systematic review which amounted to 25 articles. For the second part of the thesis, fifty-one (n=51) male u21 rugby union players' sRPE and RPC scores were collected after team, split, and gym sessions. The coaches' (n=4) RPC ratings were only collected after team sessions and split sessions. This equated to a total number of 1798 observations over 11 weeks (a total of 66 training sessions).

Results: The systematic review reported a range of correlations and differences between player and coaches' perception of training. Coaches both overestimated and underestimated session intensities. A *weak positive* relationship (rho= 0.30; $p< 0.01$) was found between player RPC (4.30 ± 1.60 AU) and coach RPC (4.95 ± 1.32) for team sessions, while a *moderate positive* relationship (rho= 0.47; $p< 0.05$) was found for split sessions (player RPC 4.32 ± 1.84 AU; coach RPC 4.19 ± 1.49 AU). A *moderate positive*

relationship (rho= 0.67; $p< 0.05$) was found between player RPC (4.32 ± 1.84 AU) and player sRPE (4.57 ± 1.59 AU) for split sessions, as well as for team sessions (RPC 4.95 ± 1.32 AU; sRPE 5.53 ± 1.51 AU; rho= 0.47; $p< 0.01$). Forwards reported higher RPC (5.32 ± 1.58 AU) compared to backs (3.35 ± 1.53 AU) for split and team sessions (forward's RPC 4.83 ± 1.49 AU; backs RPC 3.71 ± 1.52 AU). No differences in RPC and sRPE between forwards and backs were found for gym sessions ($p> 0.05$).

Discussion: The systematic review gives insight into the different factors which may influence the relationship between player and coach RPE, such as the player's and coach's experience, the player's age and sex, and the method of data collection. The utility of the RPC may be more meaningful in the skill development focused stages such as coordination training and skill adaptability, where coaches are working with fewer players, and focused on specific technical outcomes.

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Chapter 1

BACKGROUND AND SCOPE

The goal of high-performance sport

In high performance sport, coaches and practitioners aim to develop players, keep them injury free, and prepare them to perform optimally during competition (Borresen & Lambert, 2009; Impellizzeri et al., 2019). Achieving these objectives is a challenge for all sports, as it is influenced by a number of 'controllable' and 'uncontrollable' factors (Impellizzeri et al., 2020). A key 'controllable' for coaches and practitioners is training. Examples of 'controllable' factors are the type of training, the frequency of training, the duration of training- and the intensity at which it is performed.

Banister et al (1975) proposed that a player's performance can be predicted based on the difference between the fatigue and fitness stages of the athlete. Fitness has a positive influence on performance whereas fatigue has a negative influence (Banister et al., 1975). For a player to adapt optimally, there must be a balance between training load and recovery with limited negative consequences, such as fatigue (Foster et al., 2001; Morton et al., 1990). Training loads that are too high or too low with inappropriate recovery periods will lead to an increased risk of injury and/or underperformance (Gabbett, 2020).

Monitoring and managing training demands

To ensure this balance between training load and recovery is achieved, modifications to the training load (training frequency [number of sessions], duration, and intensity) are necessary to improve performance (Halson, 2014). Training load can be quantified using either internal or external units. External units of load can be defined as the amount of work performed and is measured independently of the player's internal characteristics (Borresen & Lambert, 2009; Farrow & Robertson, 2017; Soligard et al., 2016; Wallace et al., 2009). For example, the number of sessions, training duration, and movement repetitions, are all examples of external load (Borresen & Lambert, 2009; Impellizzeri et al., 2019). Internal units of load can be defined as the player's response to the external load (Borresen & Lambert, 2009; Soligard et al., 2016), and is used to measure the impact or psychophysiological stress imposed on the player (Haddad et al., 2017; Soligard et al., 2016; Wallace et al., 2009). The

stimulus for both positive and negative adaptation stems from the player's response to the external training load and is measured either objectively (e.g., heart rate) or subjectively (e.g., Rating of Perceived Exertion) (Saw et al., 2016). For example, if a player performs a 100m sprint, the distance and speed at which the 100m is covered will be defined as the external load whereas the player's heart rate (internal response) will be the internal load. Both external and internal measures are valuable in understanding the total training load placed on the player and therefore a combination of the two is important for monitoring training (Halson, 2014). Through monitoring and assessing these demands of training, coaches and practitioners can understand whether the external load has stimulated the expected internal response and whether this response has led to positive adaptations (Impellizzeri et al., 2020). If sessions do not elicit the desired outcomes, this information can be used to provide feedback to the coach to modify future training sessions (Impellizzeri et al., 2020).

RPE- a brief history

A widely used and highly practical internal load monitoring tool is the Borg's rating of perceived exertion (RPE) (Borg, 1970, 1982, 1998). RPE is a popular internal load monitoring tool as it is non-invasive, inexpensive, and user-friendly (Borresen & Lambert, 2009). It requires participants to give a numerical momentary perception of intensity on a scale that reflects the player's psychophysiological stress (Borg, 1970). RPE was developed by Gunnar Borg and increases linearly with heart rate and oxygen consumption (Borg, 1970, 1982, 1998). The RPE scale ranges from 6 (no exertion at all) to 20 (maximal exertion) which roughly corresponds with the HR range of 60 to 200 beats per minute (Borg, 1998).

Since the original Borg 6-20 scale, Gunnar Borg and colleagues have modified the scales by changing the number range and anchors. The modified scales include the Borg Category Ratio (CR) 10 scale (Borg, 1982), which ranges on a scale from 0 to 10, and the Borg CR100 scale (Borg, 2002) that ranges from 1.5 to 100. Building on the Borg CR10 scale, Foster (1998) developed a scale based on the training impulse (TRIMPS) method which represents the product of training intensity and duration (Banister

et al., 1975). The sRPE scale ranges from 0 (rest) to 10 (maximal) whereby players give one score that rates the global intensity of the entire session (sRPE) as opposed to the momentary perception of effort (Foster, 2001). The Foster CR10 scale score (Figure 1) is then multiplied by the duration of the session to derive a dimensionless term depicting the entire magnitude of the training session. By incorporating sRPE as an internal load monitoring tool it increases the accuracy of load prescription thereby avoiding over or under-training (Scantlebury et al., 2018).

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 1: Foster et al. (2001) CR10 Scale

Using sRPE in Rugby union

Rugby union is an intermittent sport based over 80 minutes (two halves of 40 minutes) (Deutsch et al., 2007). The sport is predominantly aerobic in nature and involves short bouts of high-intensity activity that are interspersed with low-intensity activity and high impact collisions (Roberts et al., 2008). The players are traditionally categorised into two positional groups, namely forwards (n= 8 players) and backs (n= 7 players) (Bradley et al., 2015). The forwards typically cover a larger distance

than forwards but perform high-intensity activities for shorter periods of time (Roberts et al., 2008). Forwards are characteristically stronger and heavier (due to the higher number of impact situations) than backs, who are characteristically shorter, leaner, and faster in comparison (Duthie et al., 2003). In rugby union, sRPE is one of the most common means of recording internal training load (Griffin et al., 2021). sRPE can also be used to quantify other training modalities such as resistance training, and conditioning (Clarke et al., 2013; Sweet et al., 2004). Rugby union is both a technically and physically demanding team sport and therefore both aspects need to be quantified and monitored respectively (Roberts et al., 2008; Hendricks et al., 2019).

Monitoring skill load

Skill load is limited to being captured by training time, training frequency and movement repetitions (Farrow & Robertson, 2017; Hendricks et al., 2019). One theory that guides the quantification of skill training, using internal load measurements, is the challenge point framework (Guadagnoli & Lee, 2004).

The challenge point framework explains how learning is related to the relationship and interaction between (1) the difficulty of a task and (2) the information available to the player. The difficulty of a task can be either nominal or functional (Guadagnoli & Lee, 2004). Functional task difficulty is the challenge of the task relative to the performer's skill level as well as the conditions under which the skill is being performed. On the other hand, nominal task difficulty refers only to the characteristics of the task and does not take into account the performer's skill level or the conditions under which the task is being performed (Guadagnoli & Lee, 2004). The nominal difficulty of a task will influence the expected performance of an individual whereas the ability of the performer, the complexity of the task, and the conditions under which the task is performed, is determined by functional task difficulty (Guadagnoli & Lee, 2004). 2021).

The framework outlines how an "optimal" level of difficulty (which is conceptualised as "challenge") needs to consider the limit of interpretable information by the individual based on pre-existing

capabilities (Guadagnoli & Lee, 2004; Hodges & Lohse, 2021). The more a task is performed, the more feedback is generated, and uncertainty is reduced (Guadagnoli & Lee, 2004). In the optimum conditions, the challenge point represents the point at which there is successful skill learning and transfer (Guadagnoli & Lee, 2004). Performance, then, allows conclusions to be made about learning (Hodges & Lohse, 2020). This framework can be used to determine the optimal challenge point for players and therefore predict and capture skill load.

Rating of Perceived Challenge (RPC)- a brief overview

With the above framework in mind, Hendricks et al (2019) proposed a method for quantifying the technical demand of a skill session based on skill acquisition theories and frameworks. The rate of perceived challenge (RPC) is a 0-10 visual analogue scale that uses technical skill-specific instructions and anchors (Hendricks et al., 2019). Instead of asking players how physically challenging a training session was (RPE), players are asked to rate how technically challenging the session was on a scale from 0 (rest) to 10 (maximal) (Figure 2). A rating of 1 is descriptively interpreted as the execution of a set of coordinated movement patterns (technique) in a low representative, highly structured environment (Hendricks et al., 2019). An RPC score of 10 represents “the proficient execution of the correct actions in response to the situation (skill proficiency) while fatigued (skill capacity)” in a competition-like environment (Figure 3) (Hendricks et al., 2018).

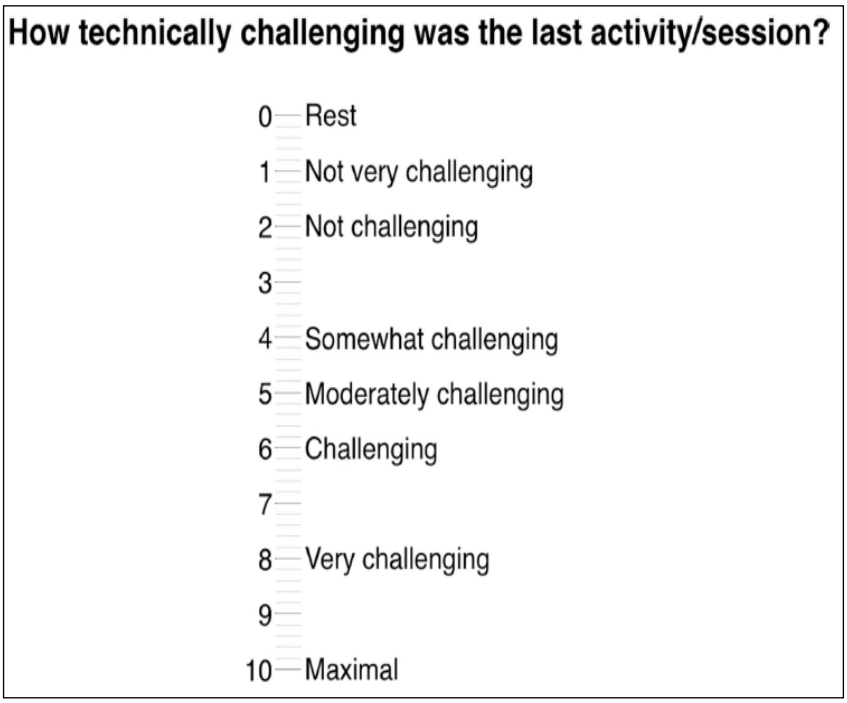


Figure 2: Hendricks et al. (2019) RPC scale

Just like RPE, the difficulty of the task and the amount of information available to the player is typically set by the coach, with the aim of creating the optimum challenge point to ensure skill retention and transfer (Guadagnoli & Lee, 2004; Hendricks et al., 2019). To meet the training session objectives, coaches must establish the difficulty of the task and the environment in which it will be performed before the session. The relationship between the two will supply the challenge point (Guadagnoli & Lee, 2004). At the end of an activity, players will rate it using the RPC scale. This score is then compared to the challenge point set by the coaches (Hendricks et al., 2019). To get a more detailed view of the athlete's workload, the RPC should be used in conjunction with other internal load measurements (e.g., RPE) as well as objective measurements (e.g., speed and repetitions) (Hendricks et al., 2019). To assess the associations between sRPE and RPC, the scores must be presented at the same time using the same method. For example, if RPE is given at the end of a session or drill, so too must RPC be collected following the session.

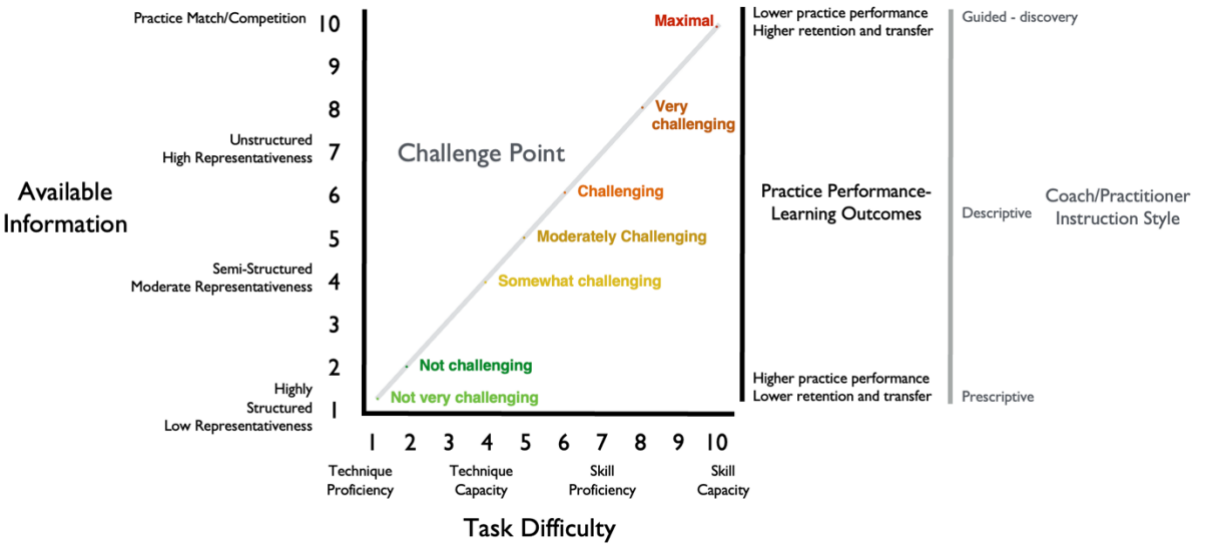


Figure 3: Technical skill training framework (Hendricks et al., 2018)

The relationship between player and coach

Numerous studies have investigated the relationship between players' and coaches' perception of intensity. In most cases, players perceive a training session as significantly harder or easier than what the coach had intended/prescribed (Barnes, 2017; Brink et al., 2014; Carvalho et al., 2018; Foster et al, 2001; Imamura et al., 1997; Nogueira et al., 2014; Rabelo et al., 2016; Scantlebury et al., 2018; Wallace et al., 2009). Continuous underestimation of the internal load of players could lead to overreaching, illness, or injury, whereas the continuous overestimation of internal load will lead to under-training (Brink & Frencken, 2018). If players do not train according to the intended session intensity it could also lead to inadequate recovery, muscle damage, and maladaptation (Brink et al., 2014; Macpherson et al., 2019; Nédélec et al., 2012). Therefore, it is suggested that coaches should give an intended-RPE as well as an observed-RPE to ensure their intended session intensity is achieved.

Furthermore, it has been suggested that there is a weaker association between players' and coaches' RPE scores during team sports when compared to individual sports (Brink et al., 2017). In team sports, coaches often give only one intended or observed RPE score for the whole team instead of giving a score for each player. Depending on the nature of the activity, this becomes problematic. Within activities, such as small sided games for example, players cover various distances at various speeds.

Therefore, players' loads will vary within the session or drill and presenting only one score for the entire team will not be an accurate reflection of the load. A player's load perception is also determined by individual characteristics such as: playing position, level of play, age, and fitness capabilities (Brink et al., 2014) and need to be taken into consideration by the coach. The RPC score and relationship between player and coach will also differ depending on the session type. Sessions that involve match scenarios may contribute to a higher RPC as well as a higher RPE. Whereas sessions that involve a high level of physical activity but not technical or tactical drills (e.g., gym or conditioning sessions) may warrant a low RPC but high RPE.

Thesis aim and purpose

There are numerous studies that investigate the relationship between player and coach perception of intensity, yet these studies have not been synthesised. Therefore, practitioners are not fully aware of all the factors that may influence this relationship. With the above in mind, this thesis will identify, evaluate, and summarize the outcomes and procedures of studies that assess the relationship between the coach's rating of intended exertion (RIE) and/or the coach's rating of observed exertion (ROE) and the players' RPE through a systematic review.

Rating of perceived challenge has not been used in a team sport setting and requires research to strengthen its construct validity. Furthermore, there has been no correlation made between RPC and other load measurements (external/internal). Building on the knowledge gained from the systematic review, an original study will be conducted to determine the relationship between player and coach RPC for different training sessions over a competitive rugby union season. Also, considering that RPC is intended to complement sRPE, a secondary aim was to explore the relationship between player RPC and sRPE.

Chapter 2

THE RELATIONSHIP BETWEEN PLAYERS' AND COACHES' PERCEPTION OF EXERTION: A SYSTEMATIC REVIEW

Introduction

Monitoring training is a common practice in sport (Borresen & Lambert, 2009; Gabbett, 2016; Halson, 2014). With improvements in technology (e.g., global positioning systems), and our understanding of psychophysiology (e.g., subjective rating scales), monitoring training has become more popular due to the immediate feedback on the player's physiological and perceptual responses (Foster et al., 2017). Through monitoring the training sessions, coaches can identify if training session goals (duration, distance, movement repetitions) are being reached and if the player is positively adapting to these stimuli.

Training load can be manipulated to elicit a desired training response (Coutts et al., 2017; Impellizzeri et al., 2019). The amount of work performed in training is known as the external load and the player's response to the work is known as the internal load (Borresen & Lambert, 2009; Impellizzeri et al., 2019). Together, they represent the training load of the session. The external load is typically captured using objective measures such as global positioning systems (GPS), accelerometers, and wearable body metrics (Haddad et al., 2017). These measures provide detailed information of the training session (e.g., duration of the sessions, distance covered) which help quantify the training session (Haddad et al., 2017). The internal load is captured using internal physiological and psychological response measures such as heart rate (physiological/objective) and subjective ratings (Borresen & Lambert, 2009; Wallace et al., 2008).

The rating of perceived exertion (RPE) is a widely used and highly practical internal load monitoring tool (Borg, 1970, 1982, 1998). RPE is a non-invasive and inexpensive tool that measures the perceived intensity of a session (Borresen & Lambert, 2009). It was developed by Borg (1970) and requires participants to give a momentary perception of intensity on a scale that increases linearly with heart rate and oxygen consumption (Borg, 1970, 1982, 1998). The Borg scale has shown to be a valid and reliable measure for differences in perceived exertion (Borg & Noble, 1974; Morgan, 1981; Skinner et

al., 1973). For example, Skinner et al. (1973) found no differences between ratings in work intensities, that were presented in a random order, and progressive exercise tests.

The original Borg RPE scale (6-20) was modified to create the Borg RPE Category Ratio (CR) 10 scale (Appendix B) which ranges from 0 to 10 (Borg, 1982). The modified CR10 scale has an increased number range to enhance discrimination at low intensity levels and stress the continuous nature of the scale (Borg et al., 1987; Marks et al., 1983). The names of the scales were given depending on the top numerical anchor e.g., CR100 (Borg & Noble, 1974; Marks et al., 1983; Skinner et al., 1973). The Borg CR100 scale (Appendix C) is a modification of the Borg CR10 scale, and it ranges from 1.5 to 100 (Borg, 2002). All these scales have been proven valid and reliable measures of perceived exertion (Borg, 2002; Borg, 1982, 1998).

In addition to the different modified versions of the scale, the point at which the rating is captured is also important. Foster and colleagues (2001) proposed that players rate the global intensity of an entire training session using a modification of the Borg CR10 scale (Foster, 1998). This scale is referred to as the session-RPE (sRPE) and is only taken post-session instead of during the exercise (Appendix D). This rating is then multiplied by the duration of the session (in minutes) which derives a dimensionless term depicting the entire magnitude of the training session (Foster, 2001). sRPE is taken 30-mins after the conclusion of the training session to prevent drills or elements at the end of training from dominating the participant's perception of the entire session (Foster, 1998). The validity and reliability of sRPE has been tested in various environments including technical and tactical sessions for individuals (e.g., cycling and karate) (Rodríguez-Marroyo et al., 2012; Tabben et al., 2013), teams (e.g., soccer and basketball) as well as in different modalities of strength and conditioning (Casamichana et al., 2013; Manzi et al., 2004; Haddad et al., 2011; Foster, 2001; Haddad et al., 2017).

While the sRPE captures the perceived exertion of the training session, Weston (2013) suggested that this may not be sensitive enough for the range of training modalities within team sports. Weston et al. (2015) recommended that the RPE score be differentiated into breathlessness (RPE-B), leg (RPE-L),

and technical (RPE-T) to represent different dimensions of effort. Due to the various demands in team sports, differential-RPE may provide coaches and practitioners with a more resourceful understanding of the stress imposed on a player in training rather than a single RPE score (Weston et al., 2014). Building on RPE-T, Hendricks, and colleagues (2018) proposed quantifying the technical demand of a skill session based on skill acquisition theories and frameworks (Hendricks et al., 2018). This measurement is referred to as the rating of perceived challenge and is a 0-10 visual analogue scale that uses technical skill-specific instructions and anchors.

Throughout the training session, coaches need to be aware of the specificity and individual characteristics that may affect the player's internal load (Haddad et al., 2017). Through appropriate and accurate load monitoring, coaches and practitioners will be able to identify fatigue, guide training prescriptions, and develop an awareness of individual adaptations (McGuigan et al., 2020). Ideally, coaches require players to execute training sessions according to the planned session intensity (Brink & Frencken, 2018). To ensure successful periodization and monitoring thereof, coaches can give an intended-RPE (RIE) which can later be compared to the player's RPE. In addition to RIE, the rating of observed exertion (ROE) can be given by the coach post-session and can establish if the training intensity observed by the coach and the intensity perceived by the player are congruent (Brink et al., 2017). RIE is better used to reflect on the 'planned' versus 'executed' session intensity whereas ROE (which considers changes within the session) reflects on the association between player and coach's perception of intensity. ROE is important to collect to compare with the intended session intensity (to avoid possible overloading and injury) as well as when you are comparing the players RPE. ROE is given at the same time that an athlete gives RPE and therefore the two are comparable as both scores are based on the same session or drill. Whereas RIE cannot be directly compared to RPE due to within-session adjustments.

RIE and ROE can be used by the coach to reflect on the player's response to training and may give a deeper assessment of the coach's ability to interpret subjective cues (Brink et al., 2017).

Both RIE and ROE are important to understand the player's response to training. The coach's and player's perception of intensity must be aligned to ensure that the session objectives are being reached (Bompa & Buzzichelli, 2015). The practitioner or sport scientist should give feedback to the coach on the player's RPE scores so that future training sessions can be altered if necessary (Brink & Frencken, 2018). Some studies have highlighted discrepancies between RIE and RPE (Brink et al., 2014; Macpherson et al., 2019; Scantlebury et al., 2018), as well as between ROE and RPE (Vaquera et al., 2017; Doeven et al., 2017). This could have negative consequences if the discrepancy is not managed appropriately. For example, if players repeatedly perceive the session load as higher than initially intended by the coach, it may be an indication of inadequate recovery and lead to muscle damage, and maladaptation (Brink et al., 2014; Nédélec et al., 2012). On the other hand, if players underestimate the training intensity, it may lead to undertraining and being underprepared for match demands (Brink & Frencken, 2018). Studies have assessed this relationship between player and coach within multiple sporting codes and over various age groups. However, the studies have not been synthesised. Furthermore, there is no clear conclusion of the patterns, habits, and characteristics that may promote or suppress the successful congruence of player and coach ratings of perceived exertion. These studies need to be synthesised to better understand the importance of training load monitoring and potentially highlight the underlying factors that lead to a mismatch.

Therefore, the purpose of this review is to identify, evaluate, and summarize the outcomes and procedures of studies that assess the relationship between the coach's rating of intended exertion (RIE) and/or the coach's rating of observed exertion (ROE) and the players' RPE.

Methods

The reporting of this systematic review was guided by the standards of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement (Page et al., 2021). The study selection process is outlined in a flow diagram (Figure 4).

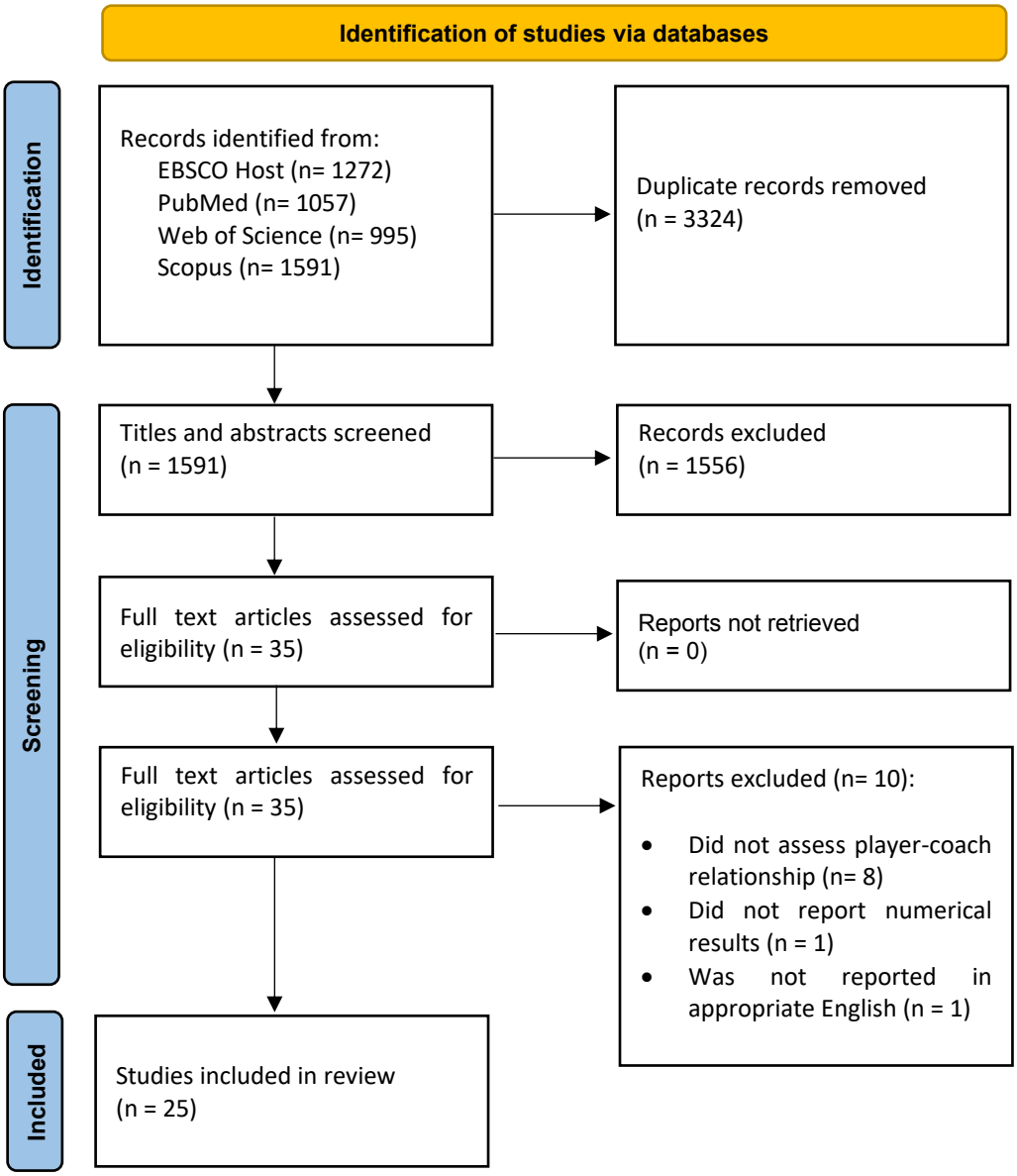
Eligibility Criteria

In order for a study to be included in this review, it needed to (1) measure the relationship, association, differences or agreement between the player's RPE of a session, exercise or drill with that intended (RIE) and/or observed (ROE) by the coaches, (2) use a valid and reliable RPE scale as a measurement tool, (3) be a full-text published article, (4) have an injury-free population.

Information sources and search strategy

Four databases were searched namely, EBSCOhost, Scopus, Web of Science, and PubMed. The search took place between June to September 2020 (last search date, 30th of September 2020). The combination of the following search terms were used to identify studies: (Train*) OR ('Training-Load') OR ('Load-monitoring') OR ('training-load-monitoring') AND ('Internal-load') OR ('subjective-ratings') OR ('perception-of-effort') OR ('perceived-exertion') OR ('perceived-stress') AND (Coach*) OR (athlete*) OR (Player*). For example, in PubMed, the search appeared as-is: ("train*"[Title/Abstract] OR "training load"[Title/Abstract] OR "load monitoring"[Title/Abstract] OR "training load monitoring"[Title/Abstract] OR "TLM"[Title/Abstract]) AND ("internal load"[Title/Abstract] OR "subjective ratings"[Title/Abstract] OR "perception of effort"[Title/Abstract] OR "perceived exertion"[Title/Abstract] OR "perceived stress"[Title/Abstract]) AND ("coach*"[Title/Abstract] OR "player*"[Title/Abstract] OR "athlete*"[Title/Abstract]). To identify any additional studies, a manual search was conducted using the reference lists of all eligible studies. Records retrieved from the database search were exported into excel where duplicates were removed. One reviewer screened all the titles and abstracts thereby removing irrelevant studies. Thereafter, the full texts of the remaining studies were retrieved for future assessment.

Figure 4: Flow diagram representing the study selection process



Reporting bias assessment

The quality of the studies included in this systematic review was evaluated using a tool developed by the NIH (National Health Institute) for the NHLBI (national heart, lung, and blood institute) by one reviewer (National Institutes of Health, 2014). The study-quality assessment tool is used for observational cohort and cross-sectional studies and consists of 14 criteria that evaluate the internal validity of the study (Table 1). Each item on the NIH quality assessment tool can be answered with a yes ("Y"), no ("N"), cannot determine ("CD"), not reported ("NR"), or not applicable ("NA").

Table 1 Quality Assessment Tool taken from the NIH

	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was the exposure(s) assessed more than once over time?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome assessors blinded to the exposure status of participants?	Was loss to follow-up after baseline 20% or less?	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?
Andrade et al., 2020	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barnes, 2017	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barroso et al., 2014	Y	Y	NR	Y	NR	Y	CD	Y	Y	Y	Y	Y	Y	Y
Barosso et al., 2015	Y	Y	NR	Y	NR	Y	N	Y	Y	Y	Y	Y	Y	Y
Brink et al., 2014	Y	Y	Y	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Brink et al., 2017	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Brink & Frencken, 2018	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Carvalho et al., 2018	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Doeven et al., 2017	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Figueiredo et al., 2019	Y	Y	Y	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Foster et al., 2001	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Imamura et al., 1996	Y	Y	NR	Y	NR	Y	N	Y	Y	N	Y	Y	Y	Y
Kraft et al 2020	Y	Y	NR	Y	NR	Y	CD	Y	Y	Y	Y	Y	Y	Y
Macpherson et al., 2019.	Y	Y	Y	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Murphy et al., 2014	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	N	Y
Nogueira et al., 2014	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Nogueira et al., 2015	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rabelo et al., 2015	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Redkva et al., 2017	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rodriguez-Marroyo et al., 2014	Y	Y	NR	Y	NR	Y	Y	Y	y	y	y	NR	Y	y
Scantlebury et al., 2018	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sinnott-O'Connor et al., 2019	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vaquera et al., 2017	Y	Y	NR	Y	NR	Y	CD	Y	Y	Y	Y	NR	Y	Y
Viveiros et al., 2011	Y	N	NR	Y	NR	Y	N	Y	Y	Y	Y	Y	Y	Y
Wallace et al., 2009	Y	Y	NR	Y	NR	Y	Y	Y	Y	Y	Y	NR	N	Y

* Y = Yes, N = No, CD = Cannot determine, NA = Not applicable, NR = Not reported

Data collection process and data items

Selected information was extracted from the studies by a single reviewer and is displayed in Table 2 and Table 3. The data extracted from each study includes the 'reference' (author), 'study characteristics' (study design, sample size, level of play, sport, coach's experience, study duration, type of analysis, scale, and event), and 'results' (RIE, ROE, RPE, RIE vs RPE and ROE vs RPE, and additional comments on the main findings). disagreements

Selection process and risk of bias assessment

Once the included articles were agreed upon, a quality assessment of the eligible articles was conducted. To assess the risk of bias in the included studies, two researchers identified studies independently based on the inclusion criteria. Whilst comparing the included studies, there were no differences found and therefore there was no discussion or additional researcher required to resolve disagreements.

Effect measures

RIE, ROE and RPE data are presented as mean ± standard deviation (SD). Statistical data are presented in Table 2 and Table 3 as they were reported in each study. Reported statistics included kappa k index (k), standardised mean difference (SMD), intercorrelation coefficients (ICC), 2-way sample t-test (t), Cohen's (d) effect size (ES), bivariate correlation of Kendall's and Mann-Whitney test, 1-way ANOVA, 2-way ANOVA, spearman rank correlation and Pearson correlation coefficient (r). If an article did not report a specific study statistic or characteristic, 'NR' (not recorded) was inserted. No assumptions were made on missing data (e.g., the gender of the participants, coaching experience, level of play, etc.).

Reporting

Study characteristics of studies that tested the relationship between RIE and RPE are reported in Table 2. Study characteristics of studies that tested the relationship between ROE and RPE are reported in Table 3. The summary of the study characteristics is reported in Table 4. Results are reported based

on the relationship measured (RIE and RPE or ROE and RPE) and if studies categorised their sessions into low, moderate, or high intensity sessions. Coaches or practitioners categorised session intensity based in the RIE (e.g., low intensity= RPE <3; moderate intensity= RPE 3-5; high intensity= RPE >5). Results also indicate if the studies used associations or differences to test the relationship. In the case where a study tested both RIE and ROE, the results were reported individually within each section. Results are indicated as they are reported in the study, including correlation interpretations. In a situation where studies present the same *r* value but different interpretations (e.g., *moderate* correlation or *small* correlation), the studies' interpretation of the *r* value was used.

Table 2 Characteristics and results of studies that test the relationship between RIE and RPE

Reference	Study Characteristics								Results			
	Study design	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**RIE**	**RPE**	**RIE vs RPE**	**Additional comments**
(Andrade et al., 2020)	*prospective observational	3; 2	Beach Volleyball	>15	3 weeks	Mean ± CI	sRPE	Week 1	6.7 ± 1.0	5.6 ± 1.2	Likely differences were shown in Strength (SMD= 0.43) and physical fitness (SMD= 0.40) training sessions	Overall coach and athlete's RPE differences decreased during the weeks of training.
								Week 2	5.0 ± 0.8	5.1 ± 1.4		
								Week 3	5.3 ± 1.1	5.2 ±1.6		
(Barnes, 2017)	*prospective observational	25; 2	Cross country running		3024 sessions	Effect Size (ES)	sRPE	Men easy intensity	Season (1): 1.3± 0.5, (2): 1.1± 0.3, (3): 1.2± 0.5, (4): 1.3± 0.5, (5): 1.5± 0.6. Season average: 1.4 ± 0.5	Season (1): 2.4± 0.5, (2): 2.5± 0.5, (3&4): 2.8± 0.9, (5): 2.1± 0.8. Season average: 2.7 ± 0.6	Players perceived as harder: ES= 2.96 ± 0.46, *p*< 0.0001	In general, athletes tended to perceive training as closer to moderate intensity throughout the season regardless of the intended session intensity by the coach. Likewise, for coach-intended easy and moderate sessions, male and female athletes reported higher intensity and training loads. For intended hard days, there was no difference between male runners and coaches, whereas females were significantly lower.
								Men moderate intensity	Season (1): 3.4± 0.6, (2): 3.4± 0.7, (3): 3.6± 0.6, (4): 3.8± 0.5, (5): 5.0; Average 3.6 ± 0.6	Season (1): 4.4± 0.8, (2): 4.3±1.2, (3): 4.7±0.4, (4): 4.2±0.2, (5): 5.2; Average: 4.4±0.7	Perceived as harder: ES= 1.21 ± 0.46, *p*= 0.00	
								Men high intensity	Season (1): 6.8± 1.0, (2): 7.1± 1.0, (3): 7.3± 0.9, (4): 7.7± 0.6, (5): 10.0; Average: 7.3 ± 1.0	Season (1): 6.9± 0.6, (2): 7.1± 1.0, (3): 7.4± 0.6, (4): 6.9± 0.6, (5): 10.0; Average: 7.3 ± 0.7	No difference: ES= 0.07 ± 0.46, p= 0.91	
								Women easy intensity	Season (1): 1.3± 0.5, (2): 1.1± 0.3, (3): 1.2± 0.5,	Season (1): 2.7± 0.7, (2): 2.3± 0.6, (3): 2.6± 0.5,	Perceived as harder: ES= 4.39 ± 0.48, *p*< 0.001	

Reference	Study Characteristics								Results			
	Study design	Sample size (n) Players; coaches	Sport	Coach's experience (years)	Study Duration	Type of analysis	Scale	Training comparators	RIE	RPE	RIE vs RPE	Additional comments
									(4): 1.3± 0.5, (5): 1.5± 0.6; Average: 1.3± 0.5	(4): 2.5± 0.8, (5): 2.0± 0.7; Average: 2.5 ± 0.7		
								Women moderate intensity	Season (1): 3.4± 0.6, (2): 3.4± 0.7, (3): 3.6± 0.6, (4): 3.8± 0.5, (5): 5.0; Average: 3.6 ± 0.6	Season (1): 3.8± 0.5, (2): 3.7± 1.1, (3): 3.6± 0.4, (4): 3.5± 0.3, (5): 5.2; Average: 3.7 ± 0.6	No difference: ES= 0.18 ± 0.48, *p*= 0.38	
								Women high intensity	Season (1): 6.8± 1.0, (2): 7.1± 1.0, (3): 7.3± 0.9, (4): 7.7± 0.6, (5): 10.0; Average: 7.3 ± 1.0	Season (1): 6.7± 0.3, (2): 6.6± 1.2, (3): 7.1± 0.8, (4): 7.2± 1.0, (5): 9.4; Average: 6.9 ± 0.9	*Moderate lower* difference: ES= 0.91± 0.48, *p*= 0.006)	
(Barroso et al., 2014)	*prospective observational	160 (46 11–12-year-olds, 65 13–14-year-olds, and 49 15–16-year-olds); 9	Swimming	>11	9 sessions	Pearson product-moment correlation and 2-way ANOVA	sRPE	Overall			*r*= 0.60, *p*< .001 (*positive moderate* correlation)	Agreement increased with age and experience. The younger age groups differed from the coach in all 3 intensity categories (low, moderate, and high). No difference found in the 15-16yr category for easy and moderate sessions, however, athletes underestimated the intended difficult sessions.
								11-12yrs			*r*= 0.31, *p*< .001 $F_{2,435}$ = = 28.86	
								13-14yrs			*r*= 0.50, *p*< .001 $F_{2,606}$ = 20.78	
								15-16yrs			*r*= 0.74, *p*< .001 *No difference in easy and moderate intensity sessions but* $F_{2,462}$ = 10.47 for high intensity sessions	
(Barroso et al., 2015)	*Experimental	13; 1	Swimming	7 years	4 sessions	1-sample t-test.	Borg CR10	10x 100m	3	NR	*p*= 0.57	The coach overestimated sRPE in
								20 x 100m	4	NR	*p*= 0.28	

Reference	Study Characteristics								Results			
	Study design	Sample size (n) Players; coaches	Sport	Coach's experience (years)	Study Duration	Type of analysis	Scale	Training comparators	RIE	RPE	RIE vs RPE	Additional comments
						Significance was set at p< 0.05.		10x 200m	5	NR	*P*= 0.005	longer repetition distances (i.e., 200 m and 400 m).
								5x 400m	6	NR	*P*= 0.033	
(Brink et al., 2014)	*prospective observational	33; 2	Soccer	Numerous years at the highest level.	2446 sessions	Pearson correlation and two-way ANOVA	Borg (6-20)	Overall	13.6 ± 1.59	14.0 ± 1.72	*Weak* correlations: *r*= 0.24, *p*< 0.0001	First year players (u17's) perceived the intensity of training sessions as significantly harder than the coach had intended (13.7 ± 1.6 vs 13.3 ± 1.6). No differences were found in second year players. Overall, players perceived sessions as harder than what was intended by the coaches, with *weak* correlations on intensity, duration (*r*= 0.49), and training load (*r*= 0.41).
								Easy Intensity	11.3 ± 1.1	13.3 ± 1.0	Perceived as significantly harder by the players (*p*< 0.0001).	
								Moderate Intensity	13.4 ± 0.5	13.9 ± 1.6	Perceived as significantly harder by the players (*p*< 0.0001)	
								High Intensity	15.3 ± 1.1	14.4 ± 1.7	Perceived as significantly less intense by the players (*p*< 0.05).	
(Brink et al., 2017)	*prospective observational	31; 2	Soccer	18-23	977 sessions	Pearson correlation coefficients and Bland Altman procedures for agreement	Borg (6-20)	Overall	13.3 ± 2.1	13.6 ± 2.2	*r*= 0.58, *p*< 0.01. Mean difference: -0.31± 1.99, CI95% -0.43, -0.19	Coach intended RPE scores were given for each individual player
(Brink & Frencken, 2018)	Quasi-experimental using a feedback intervention	12; 1	Soccer	13 years of professional coaching	26 Sessions	Pearson Correlation coefficients and Bland Altman procedures for agreement	Borg (6-20)	No feedback	15.0 ± 1.4	15.0 ± 1.9	The mean discrepancy was the same between periods of feedback and no feedback (*p*< 0.01).	RIE was given for each individual player. Feedback was given for the 1st mesocycle (no feedback period) as well as immediately after the training sessions in the 2nd mesocycle (feedback period).
								Feedback	14.8 ± 1.8	14.8 ± 2.4		

Reference	Study Characteristics										Results	
	Study design	Sample size (n) Players; coaches	Sport	Coach's experience (years)	Study Duration	Type of analysis	Scale	Training comparators	RIE	RPE	RIE vs RPE	Additional comments
(Carvalho et al., 2018)	*prospective observational	12; 1	Soccer	5 years	59 sessions	Bivariate correlation of Kendall's and Mann-Whitney test.	sRPE	Overall			*r*= 0.73, *p*= 0.001	Overall *strong* correlation between coach's and athletes' RPE. When training sessions were divided into intensity categories, only the difficult training sessions did not present differences.
								Easy Intensity			*p*= 0.046	
								Moderate Intensity			*p*= 0.001	
								Hard Intensity			*p*= 0.75	
(Figueiredo et al., 2019)	*prospective observational	16; 2	Soccer		15 sessions	Two sample t-test	Borg CR10	Overall	5.8 ± 1.6	5.6 ± 1.5	t= 0.49; *p*= 0.62	Overall, no significant differences in s-RPE between players and coaches during the intensification and taper phase (p≤ 0.05).
								Intensification phase	6.6 ± 1.5	6.3 ± 1.5	t= 0.45; *p*= 0.65	
								Taper phase	4.4 ± 1.1	3.8 ± 1.4	t= 0.71; *p*= 0.50	
(Foster, 2001)	*prospective observational	15; 3 (each athlete had 1 coach)	Middle- and long-distance Runners		5 weeks	Two-way ANOVA. Alpha set at 0.05	sRPE	Overall			*r*= 0.75	Athletes overestimated intended easy sessions and underestimated intended hard sessions.
								Easy intensity	1.8 ± 0.5	2.4 ± 1.4	Players significantly overestimated	
								Intermediate intensity	3.4 ± 0.7	3.4 ± 1.7	No significant differences	
								Hard intensity	7.1 ± 1.2	6.2 ± 2.5	Players significantly underestimated	
(Imamura et al., 1997)	Experimental	14 (6 Blackbelt (BB) and 8 Whitebelt (WB)); 9	Karate		4 sessions	Mann Whitney U	Borg (6-20)	Whitebelt 1000 punches	14.8 ± 1.8	12.8 ± 1.2	There was no significant difference (*p*< 0.05) between the coaches and WB group in RPE for 1000 kicks. RPE for 1000 punches in both WB and BB groups and for 1000 kicks in the BB group were significantly (*p*< 0.05) lower than expected by the coach.	Coaches and WB group RPE for 1000 kicks were significantly higher than the BB group.
								Whitebelt 1000 kicks	16.7 ± 1.7	16.3 ±1.5		
								Blackbelt 1000 punches	14.8 ± 1.8	12.2 ± 1.2		
								Blackbelt 1000 kicks	16.7 ± 1.7	14.2 ±1.2		
		56; 4						Overall	5.5 ± 1.9	4.5 ± 1.9	*r*= 0.65	

Reference	Study Characteristics										Results	
	Study design	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**RIE**	**RPE**	**RIE vs RPE**	**Additional comments**
(Kraft et al., 2020)	Prospective observational		Volleyball, soccer, and basketball		433 sessions	Pearson Correlation and t-test	Omni 10 scale	Women's Volleyball	5.2 ± 1.0	4.6 ± 1.4	*r*= 0.31	Overall, the coach overestimated the session intensity except in women's soccer.
								Women's Soccer	3.6 ± 1.9	3.3 ± 1.9	*r*= 0.79	
								Men's Basketball	7.3 ± 0.7	5.2 ± 1.5	*r*= 0.42	
								Women's Basketball	5.9 ± 1.4	5.1 ± 1.8	*r*= 0.71	
								Overall Easy Intensity		2.9 ± 1.1		
								Overall Moderate Intensity		5.6 ± 0.7		
								Overall Hard Intensity		8.2 ±0.4		
(Macpherson et al., 2019)	Exploratory investigation	16; 1	Soccer	>20 years in professional and semi-professional soccer	7 sessions	Equivalence tests.	Borg CR10 0	RPE- breathless-ness	42 ± 15	40 ± 21	All coach and player differential-RPE comparisons were deemed not realistically equivalent.	
								RPE- Legs	47 ± 14	41 ± 20		
								RPE- technical tasks	53.6 ± 7.5	43 ± 12		
(Murphy et al., 2014)	*prospective observational	14; 6	Tennis	10 ± 3 years at elite level.	16 weeks	One-way ANOVA, ICC	Borg CR10	Overall	5.5 ± 1.2	6.2 ± 1.4	Significantly different (p< 0.05) from athlete perception	Coach intended was strongly correlated to coach observed RPE (p= 0.63, 0.79 ICC).
(Nogueira et al., 2014)	*prospective observational	15; 1	Volleyball	NR	34 Sessions	Kappa (K) index and one way ANOVA along with Tukey's post-hoc.	sRPE	Overall	NR		*k*= 0.64	Athletes of all positions presented good levels of agreement with the perception of the coach, even though the coach did not specify the intensity of the sessions for each position. Athletes tend to overestimate sessions classified as easy and tend to underestimate sessions classified as hard. However, in moderate
								Setter	NR		*k*= 0.78	
								Liberos	NR		*k*= 0.79	
								Outside hitters	NR		*k*= 0.75	
								Middle blockers	NR		*k*= 0.74	
								Opposites	NR		*k*= 0.75	
								Intended easy sessions	< 3	3.4% perceived it as easy, while 90% perceived it as moderate.		

Reference	Study Characteristics								Results			
	Study design	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**RIE**	**RPE**	**RIE vs RPE**	**Additional comments**
								Intended moderate sessions	3-5	67.8% perceived it as moderate.		sessions, there was a greater agreement between athletes and coach.
								Intended hard sessions	>5	37.1% agreed with the coach while 53.3% perceived it as moderate.		
(Nogueira et al., 2015)	*prospective observational	17; 1	Swimming	NR	18 Sessions	ICC, Kappa index (k)	sRPE	Overall	3.4 ± 1.2	3.4 ± 1.9	*Very high* correlation: ICC= 0.80 (95% CI = 0.75-0.84), *p*= 0.001	Highest agreement was in easy and heavy training (88%). For moderate intended intensity sessions, 49% of the athletes had the same perception of intensity, while 37% perceived it as easy and 14% perceived it as hard.
								Transformation Phase	3.9 ± 1.4	4.2 ± 2.0	*Very high* correlation: ICC= 0.79 (95% CI= 0.71- 0.84), *p*= 0.001.	
								Taper Phase	2.9 ± 0.3	2.2 ± 0.8	*Low* correlation: ICC= 0.19 (95% CI= -0.10-0.41), *p*= 0.001	
(Rabelo et al., 2016)	*prospective observational	18; 1	Futsal	3 years' experience with using the RPE scale	314 sessions	RPE scores presented as Mean ± 90% CL. Relationship presented as difference in mean values; ± 90% CL.	Borg CR10	**Comp 1:**				Overall, the results demonstrated that in all season periods and zone intensities, the players perceived a lower training load than that intended by the coach. In addition, a greater discrepancy was found between the coach's RIE and players' RPE toward the end of the season, as well as for moderate and high training loads.
								a) Low (b) Moderate (c) High	(a) 5.3 ± 0.7; (b) 4.9 ± 0.5; (c) 6.4 ± 0.6	(a) 4.7 ± 0.6; (b) 4.3 ± 0.5; (c) 5.1 ± 0.4	(a) 0.3; ± 0.3 (b) 0.7; ± 0.2 (c) 1.3; ± 0.2.	
								Inter-comp:				
								Intensity: (a)Low (b) Moderate (c) High	(a) NR; (b) 5.5 ± 0.5 (c) 7.6 ± 0.5	(a) NR (b) 4.8 ± 0.6 (c) 5.4 ± 0.6	(a) NR (b) 0.8; ± 0.4 (c) 2.2; ± 0.4.	
								Comp 2:				
								Intensity: (a) Low (b) Moderate (c) High	(a) 3.0 ± 1.0; (b) 6.4 ± 0.5 (c) 7.5 ± 0.8	(a) 3.7 ± 0.8; (b) 4.7 ± 0.6; (c) 6.0 ± 0.4	(a) 0.7; ± 1.7 (b) 2.2; ± 0.6 (c) 1.5; ± 0.4.	
(Redkva et al., 2017)	*prospective observational	24; 2	Soccer	Professional	22 sessions (3 weeks)	Mean ± SD, Pearson correlation coefficient,	sRPE	Overall Training types (Technical, Tactical, and Physical)	6.7 ± 1.78	6.8 ± 1.43	sRPE: *Moderate* correlation: *r*= 0.60; *p*= 0.003; ES = 0.05	No statistical differences were found when comparing the S-RPE prescribed by

Reference	Study Characteristics							Results				
	Study design	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**RIE**	**RPE**	**RIE vs RPE**	**Additional comments**
						Effect sizes (ESs, Cohen's d), One way ANOVA						coaches and perceived by soccer players (p>.05) in the different training types.
(Scantlebury et al., 2018)	Observational and longitudinal	37 (9 hockey, 8 netball, 10 rugby, and 10 soccer); 4 (1 coach per sport)	Hockey, netball, rugby union and soccer	>5 years	219 sessions	A univariate analysis of variance and associated 95% confidence intervals (95% CI), and Cohen's d effect size	Borg CR10	Overall	3.6 ± 1.2	3.5 ± 1.8	*Moderate* correlation: r= 0.39; 95% CI 0.27-0.49	*Small* and *moderate* within participant correlations were found after sessions intended to be easy, moderate, and hard, respectively.
								Intended Easy sessions	1.9 ± 0.3	3.8 ± 2.2	*Moderate* correlation: r= 0.39; 95% CI 0.02-0.67; ES= 1.17; 95% CI= 0.7 to 1.65.	
								Intended moderate sessions	3.2 ± 0.4	2.9 ± 1.2	*Small* correlation: r= 0.27; 95% CI 0.1- 0.43; Likely small differences: ES= −0.36; 95% CI= −0.56 to −0.11	
								Intended hard sessions	5.2 ± 0.6	4.5 ± 2.1	*Moderate* correlation: r= 0.46; 95% CI 0.25-0.63; *Likely small differences*: ES= −0.46; CI95% −0.72 to −0.20	
(Sinnott-O'Connor et al., 2019)	*prospective observational	4; 1	Swimming	Professional	16 sessions	Pearson's product moment correlation and 2-way ANOVA.	Borg CR10	Intended easy sessions			*Small* correlation: r= 0.43, p< 0.05	The intended sRPE of the coach was lower than that of the athletes across all 3 training intensities. Association improved as session intensity increased.
								Intended moderate sessions			*Moderate* correlation: r= 0.58, p< 0.01	
								Intended high sessions			*Moderate* correlation: r= 0.64, p< 0.05	
(Viveiros et al., 2011)	*experimental	40; 4	Judo	NR	4 sessions	t-test	sRPE	Session 1	4	6.0 ± 0.7	p< 0.0001	RPE was higher than RIE in all training sessions.
								Session 2	3	7.6 ± 0.5	p< 0.0001	
								Session 3	5	5.8 ± 1.6	p< 0.02	
								Session 4	3	7.0 ± 0.7	p< 0.0001	
(Wallace et al., 2009)	*experimental	12; 2	Swimming	Qualified swimming instructors	20 sessions	2-way ANOVA, Effect size (ES) (Cohen d.	Borg CR10	Overall			r= 0.84; p< 0.01	RIE was lower than RPE for low-intensity sessions, and higher
								Low intensity	<3		*Moderate-sized effects* (d = 0.67)	

Reference	Study Characteristics									Results	
	Study design	Sample size (n) Players; coaches	Sport	Coach's experience (years)	Study Duration	Type of analysis	Scale	Training comparators	RIE	RPE	RIE vs RPE	Additional comments
						Statistical significance was set at p≤ 0.05.		Moderate intensity	3-5		*Trivial ES differences* (d = 20.14)	than RPE for high-intensity sessions.
								High Intensity	>5		*Moderate-sized effects* (d = 20.50)	

*= study design not explicitly reported and based on description in methods, ANOVA= analysis of variance, NR= not reported; ICC= intercorrelation coefficient, CL= confidence limits, CI= confidence intervals, CR= category ratio, SMD= standardised mean differences

Table 3 Characteristics and results of studies that test the relationship between ROE and RPE

Reference	Study Characteristics								Results			
Author	**Study design**	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**ROE**	**RPE**	**ROE vs RPE**	**Additional comments**
(Brink et al., 2017)	*prospective observational	31; 2	Soccer	18-23	977 sessions	Pearson correlation coefficients and Bland Altman procedures for agreement	Borg (6-20)	Overall	13.3 ± 2.2	13.6 ± 2.2	*r*= 0.64, *p*< 0.01. Mean difference: -0.37 ± 1.87, CI95%= -0.49, -0.25	Coach intended and observed RPE scores were given for each individual player.
Brink & Frencken, 2018)	Quasi-experimental using a feedback intervention	12; 1	Soccer	13 years of professional coaching	26 Sessions	Pearson Correlation coefficients and Bland Altman procedures for agreement	Borg (6-20)	No Feedback	15.1 ± 1.5	15.0 ± 1.9	Discrepancy between ROE and RPE was significantly smaller in the feedback period.	The coach gave an intended and observed score for each individual player. Feedback was given for the 1st mesocycle (no feedback period) as well as immediately after the training sessions in the 2nd mesocycle (feedback period).
								Feedback	15.2 ± 2.0	14.8 ± 2.4		
(Doeven et al., 2017)	Observational	14; 1	Basketball	>10 years of professional coaching	15 matches over 6 weeks	Bivariate Pearson Correlation, paired sample t-test, Effect size (Cohen's d) and 90% CI.	Borg (6-20)	Overall	16.1 ± 1.4	15.6 ± 2.3	*r*= 0.25 (*p*< 0.01). t=-2.21, df= 112, *p*= 0.029, ES= -0.26, CI=- 0.48 to -0.04	Coach gave individual scores to each player. There was a *weak* relationship between coach observed RPE and the players perceived RPE.
(Kraft et al., 2020)	Prospective observational	56; 4	Volleyball, soccer, and basketball		433 sessions	Pearson Correlation and t-test	Omni 10 scale	Overall	5.0 ± 1.9	4.5 ± 1.9	*r*= 0.83	Overall, the coach overestimated the session intensity except in women's soccer.
								Women's volleyball	5.5 ± 1.0	4.6 ± 1.4	*r*= 0.32	
								Women's soccer	3.0 ± 1.8	3.3 ± 1.9	*r*= 0.72	
								Men's basketball	6.4 ± 0.9	5.2 ± 1.5	*r*= 0.48	
								Women's basketball	5.5 ± 1.6	5.1 ± 1.8	*r*= 0.60	
								Overall easy Intensity	3.7 ± 1.9	2.9 ± 1.1	*r*= 0.58	
								Overall moderate Intensity	6.1 ± 1.2	5.6 ± 0.7	*r*= 0.28	

Reference	Study Characteristics										Results	
Author	**Study design**	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**ROE**	**RPE**	**ROE vs RPE**	**Additional comments**
								Overall Hard Intensity	6.5 ± 1.2	8.2 ±0.4	$r = -0.26$	
(Macpherson et al., 2019)	Exploratory investigation	16; 1	Soccer	>20 years in professional and semi-professional soccer	7 sessions	Equivalence tests. Effects were declared relevant if the outcome probability was likely (≥75%).	Borg CR100	RPE- breathlessness	37 ± 15	40 ± 21	Agreement was observed between coach observed and player reported RPE-T scores.	Findings suggest the coach was able to interpret player technical and tactical external cues (e.g., skill execution or tactical positioning) better than physical cues (e.g., sweating and body language).
								RPE- Legs	45 ± 24	41 ± 20		
								RPE- technical tasks	42 ± 14	43 ± 12		
(Murphy et al., 2014)	*prospective observational	14; 6	Tennis	10 ± 3 years at elite level.	21 ± 3 (16 weeks)	One-way ANOVA, ICC	Borg CR10	Overall	5.4 ± 1.1	6.2 ± 1.4	Significantly different ($p < 0.05$) from athlete perception	Coach intended was strongly correlated to coach observed RPE ($p = 0.63$, 0.79 ICC).
(Rodríguez-Marroyo et al., 2014)	*prospective observational	12; 4 (2 beginner coaches and 2 expert coaches)	Volleyball	Experts (>10) beginners (≤1)	15 weeks	Pearson correlation and ICC	Borg CR10	Overall	Expert coach= 3.7 ± 1.1, Beginner coach= 3.8 ± 1.0	4.0 ± 1.1	Expert coaches and players: $r = 0.70$, ICC= 0.72. Beginner coaches and players: $r = 0.72$, ICC= 0.81.	Expert coaches and beginner coaches' correlation: $r = 0.80$, ICC= 0.84. The only significant differences between coaches (both expert and beginner) and the players were during physical training ($p < 0.01$).
								Physical training sessions	Expert coach= 4.2 ± 1.0, Beginner coach= 4.3 ± 0.8	5.7 ± 0.8		
								Technical-tactical sessions	Expert coach= 3.7 ± 1.0, Beginner coach= 3.6 ± 1.0	3.7 ± 0.8		
								Match	Expert coach= 4.0 ± 1.3, Beginner coach= 4.1 ± 1.2	4.3 ± 1.4		

Reference	Study Characteristics								Results			
Author	**Study design**	**Sample size (n) Players; coaches**	**Sport**	**Coach's experience (years)**	**Study Duration**	**Type of analysis**	**Scale**	**Training comparators**	**ROE**	**RPE**	**ROE vs RPE**	**Additional comments**
(Scantlebury et al., 2018)	Observational and longitudinal	37 (9 hockey, 8 netball, 10 rugby, and 10 soccer); 4 (1 coach per sport)	Hockey, netball, rugby union and soccer	>5 years	219 sessions	A univariate analysis of variance and associated 95% confidence intervals (95% CI), and Cohen's d effect size	Borg CR10	Overall	3.5 ± 1.1	3.5 ± 1.8	*Large* correlation: *r*= 0.63; 95% CI 0.54- 0.70	When assessing session intensity, coaches will focus on the difficulty of the session and provide an RPE based on the training activity alone. However, RPE can be affected by external sources of stress such as school work or social problems.
								Observed easy sessions	2.3 ± 0.9	3.8 ± 2.2	*Large* Correlation: *r*= 0.54; 95% CI 0.09–0.76; ES 0.83; 0.4 to 1.28	
								Observed moderate sessions	3.1 ± 0.4	2.9 ± 1.2	*Small* correlation: *r*= 0.20; 95% CI 0.02–0.36; ES −0.29; −0.46 to −0.11	
								Observed hard sessions	4.6 ± 1.1	4.5 ± 2.1	*Very large* correlation: 0.79; 95% CI 0.68–0.8; ES= −0.05; −0.24 to 0.36	
(Vaquera et al., 2018)	*prospective observational	12; 1	Basketball	18 years with u16 and u18 players	15 sessions	Data expressed as difference in mean ±90% CL. Independent sample t-test. significance was set at the $p \leq$ 0.05 level.	Borg CR10	SSG 1v1			SMD= 1.13 (0.92–1.34), *p*< 0.0001	There were significant differences in athletes' and coaches' perception of exertion in all games (all *p*< 0.0001 apart from 5v5 *p*= 0.0019).
								SSG 2v2			SMD= 1.72 (1.56–1.88), *p*< 0.0001	
								SSG 5v5			SMD= 0.63 (0.31–0.94), *p*= 0.0019	
								SSG 3v2			SMD= 2.20 (1.92–2.48), *p*< 0.0001	

*= Study design not explicitly reported and based on description in methods, ANOVA= analysis of variance, NR= not reported, r= Correlation Coefficient, ICC= intercorrelation coefficient, ES= Effect sizes, CL= confidence limits, k= Kappa k Index, t= t-test, CI= confidence intervals, CR= category ratio, SMD= standardised mean differences

Study characteristic statistics

The sample size of players ranged from 3 (Andrade et al., 2020) to 160 (Barroso et al., 2014) and the sample size of coaches ranged from 1 (Andrade et al., 2020; Barroso et al., 2015; Brink & Frencken, 2018b; Carvalho et al., 2018; Nogueira et al., 2015; Doeven et al., 2017; Macpherson et al., 2019; Nogueira et al., 2014; Sinnott-O'Connor et al., 2019; Vaquera et al., 2018) to 9 (Barroso et al., 2014; Imamura et al., 1997).

Table 4 Summary of included studies that investigated team sports

Reference	Training comparators	Result
Andrade et al., 2020	Week 1	PU
	Week 2	
	Week 3	
Brink et al., 2014	Intended easy intensity	PO
	Intended moderate intensity	PO
	Intended high intensity	PU
Brink et al., 2017	Overall RIE vs RPE	PO
	Overall ROE vs RPE	
Brink & Frencken, 2018	No feedback period RIE vs RPE	
	No feedback period ROE vs RPE	
	Feedback period RIE vs RPE	
	Feedback period ROE vs RPE	
Carvalho et al., 2018	Intended easy intensity	PO
	Intended moderate intensity	PO
	Intended hard intensity	
Doeven et al., 2017	Overall ROE vs RPE	PU
Figueiredo et al., 2019	Intensification phase	
	Taper phase	
Kraft et al 2020	Women's volleyball RIE vs RPE	PU
	Women's soccer RIE vs RPE	
	Men's Basketball RIE vs RPE	PU
	Women's basketball RIE vs RPE	
	Women's volleyball ROE vs RPE	PU
	Women's soccer ROE vs RPE	
	Men's Basketball ROE vs RPE	PU
	Women's basketball ROE vs RPE	
Macpherson et al., 2019.	RPE-breathlessness RIE vs RPE	PU
	RPE- legs RIE vs RPE	PU
	RPE- technical RIE vs RPE	PU
	RPE-breathlessness ROE vs RPE	PO
	RPE- legs ROE vs RPE	PU
	RPE- technical ROE vs RPE	
Nogueira et al., 2014	Setter	
	Liberos	
	Outside hitters	
	Middle blockers	
	Opposites	
Rabelo et al., 2015	Preseason intended low intensity	
	Preseason intended moderate intensity	

Reference	Training comparators	Result
	Preseason intended high intensity	PU
	Comp 1 intended low intensity	
	Comp 1 intended moderate intensity	
	Comp 1 intended high intensity	PU
	Inter-comp intended moderate intensity	
	Inter-comp intended high intensity	PU
	Comp 2 intended low intensity	
	Comp 2 intended moderate intensity	PU
	Comp 2 intended high intensity	PU
Redkva et al., 2017	Overall RIE vs RPE	
Rodriguez-Marroyo et al., 2014	Expert coaches	
	Beginner coaches	
Scantlebury et al., 2018	Intended easy intensity	PO
	Observed easy intensity	PO
	Intended moderate intensity	PU
	Observed moderate intensity	PU
	Intended hard intensity	PU
	Observed hard intensity	
Vaquera et al., 2017	SSG 1v1	PO
	SSG 2v2	PO
	SSG 5v5	
	SSG 3v2	PO

Red= Significant difference or no association (r< 0.60; k< 0.60; ICC< 0.60; ES> 1.0; p> 0.05),
Green= association or no significant difference (r≥ 0.60; k≥ 0.60; ICC ≥ 0.60; ES≤ 1.0; p< 0.05),
PO= player overestimation,
PU= player underestimation

Table 5 Summary of studies that investigated individual sports

Reference	Training comparators	Result
Barnes, 2017	Men intended easy intensity	PO
	Men intended moderate intensity	PO
	Men intended hard intensity	
	Women intended easy intensity	PO
	Women intended moderate intensity	
	Women intended hard intensity	PU
Barroso et al., 2014	11-12 yrs old	PO
	13-14 yrs old	PO
	15-16 yrs old	
Barosso et al., 2015	10 x 100m	
	20 x 100m	
	10 x 200m	PU
	5 x 400m	PU
Foster et al., 2001	Intended easy intensity	PO
	Intended intermediate intensity	
	Intended hard intensity	PU
Imamura et al., 1996	Whitebelt 1000 punches	PU
	Whitebelt 1000 kicks	
	Blackbelt 1000 punches	PU
	Blackbelt 1000 kicks	PU
Murphy et al., 2014	Overall RIE vs RPE	PO

Reference	Training comparators	Result
	Overall ROE vs RPE	PO
Nogueira et al., 2015	Transformation phase	
	Taper phase	PU
Sinnott-O'Connor et al., 2019	Intended easy intensity	PO
	Intended moderate intensity	PO
	Intended high intensity	
Viveiros et al., 2011	Session 1	PO
	Session 2	PO
	Session 3	PO
	Session 4	PO
Wallace et al., 2009	Overall RIE vs RPE	

Red= Significant difference or no association (r< 0.60; k< 0.60; ICC< 0.60; ES> 1.0; p> 0.05),
Green= association or no significant difference (r≥ 0.60; k≥ 0.60; ICC ≥ 0.60; ES≤ 1.0; p< 0.05),
PO= player overestimation,
PU= player underestimation

Table 6. Summary of study characteristics

Characteristic	Number of studies (n)	References
Studies that investigated team sports (soccer, hockey, basketball, netball, rugby union, futsal, volleyball, and beach volleyball)	15	Andrade et al (2020); Brink et al (2014; Brink et al (2017); Brink & Frencken (2018), Carvalho et al (2018); Doeven et al (2017); Figueiredo (2019); Kraft et al (2020); Macpherson et al (2019); Nogueira et al (2014); Rabelo et al (2016); Redkva et al (2017); Rodríguez-Marroyo et al (2014); Scantlebury et al (2018); Vaquera et al (2018).
Studies that Investigated individual sports (swimming, judo, karate, tennis, middle-long distance running, and cross country running)	10	Barnes (2017); Barroso et al (2014); Barroso et al (2015); Foster (2001); Imamura et al (1997); Murphy et al (2014); Nogueira et al (2015); Sinnott-O'Connor et al (2019); Viveiros et al (2011); Wallace et al (2009).
Studies that investigated the Intended-perceived relationship	16	Andrade et al (2020); Barnes (2017); Barroso et al (2014); Barroso et al (2015); Brink et al (2014); Carvalho et al (2018); Figueiredo (2019); Foster (2001); Imamura (1997); Nogueira et al (2014); Nogueira et al (2015); Rabelo et al (2016); Redkva et al (2017); Sinnott-O'Connor et al (2019); Viveiros et al (2011); Wallace et al (2009).
Studies that investigated the observed-perceived relationship	3	Doeven et al (2017); Rodríguez-Marroyo et al (2014); Vaquera et al (2018).
Studies that measured both the intended-perceived and observed-perceived relationship	6	Brink et al (2017); Brink & Frencken (2018); Kraft et al (2020); Macpherson et al (2019); Murphy et al (2014); Scantlebury et al (2018).
Studies that tested female players	2	Andrade et al (2020); Rodríguez-Marroyo et al (2014)
Studies that tested male players	6	Barroso et al (2015); Figueiredo (2019); Imamura et al (1997); Nogueira et al (2014); Redkva et al (2017); Vaquera et al (2018).
Studies that tested both male and female players	7	Barnes (2017); Foster (2001); Kraft et al (2020); Murphy et al (2014); Scantlebury et al (2018); Sinnott-O'Connor et al (2019); Wallace et al (2009).
Studies that did not disclose the sex of the players	10	Nogueira et al (2015); Barroso et al (2014); Brink et al (2014); Brink et al (2017) Brink & Frencken (2018); Carvalho et al (2018); Doeven et al (2017); Macpherson et al (2019); Rabelo et al (2016); Viveiros et al (2011)
Studies that assessed players between 14-17 years of age	6	Brink et al (2017); Carvalho et al (2018); Murphy et al (2014); Nogueira et al (2015); Scantlebury et al (2018); Vaquera et al (2018).
Studies that assessed players >18 years of age	14	Andrade et al (2020); Barroso et al (2015); Brink & Frencken (2018); Doeven et al (2017); Figueiredo (2019); Foster (2001); Imamura et al (1997); Kraft et al (2020); Macpherson et al (2019); Nogueira et al (2014); Rabelo et al (2016); Redkva et al (2017); Rodríguez-Marroyo et al (2014); Wallace et al (2009).
Studies that assessed players over more than one age group	4	Barnes (2017); Barroso et al (2014); Brink et al (2014); Sinnott-O'Connor et al (2019)

Characteristic	Number of studies (n)	References
Studies that used the Borg CR10 scale (Borg, 1982; Borg, 1998)	9	Barroso et al (2015); Figueiredo (2019); Murphy et al (2014); Rabelo et al (2016); Rodríguez-Marroyo et al (2014); Scantlebury et al (2018); Sinnott-O'Connor et al (2019); Vaquera et al (2018); Wallace et al (2009).
Studies that used the Foster CR10 RPE scale (Foster et al.,2001)	9	Andrade et al (2020); Barnes (2017); Barroso et al (2014); Carvalho et al (2018); Foster (2001); Nogueira et al (2014); Nogueira et al (2015); Redkva et al (2017); Viveiros et al (2011).
Studies that used the Borg (6-20) RPE scale (Borg, 1970; Borg 1998)	5	Brink et al (2014); Brink & Frencken (2018); Carvalho et al (2018); Doeven et al (2017); Imamura et al (1997)
Studies that used the Borg centiMax (CR100) scale (Borg & Borg, 2002)	1	Macpherson et al (2019)
Studies that used the Omni verbal cues for adults scale (0-10) (Robertson, 2004)	1	Kraft et al (2020)
Studies that investigated player-coach relationship using Pearson correlation coefficients	8	Barroso et al (2014); Brink et al (2014); Brink et al (2017); Brink & Frencken (2018); Doeven et al (2017); Kraft et al (2020); Redkva et al (2017); Rodríguez-Marroyo et al (2014).
Studies that investigated player-coach relationship using Effect sizes	6	Barnes (2017); Doeven et al (2017); Redkva et al (2017); Scantlebury et al (2018); Sinnott-O'Connor et al (2019); Wallace et al (2009).
Studies that investigated player-coach relationship using Paired t-tests	5	Barroso et al (2015); Doeven et al (2017); Figueiredo (2019); Kraft et al (2020); Vaquera et al (2018).
Studies that investigated player-coach relationship using Analysis of variance	5	Brink et al (2014); Foster (2001); Nogueira et al (2014); Sinnott-O'Connor et al (2019); Wallace et al (2009)
Studies that investigated player-coach relationship using standardised mean differences	4	Andrade et al (2020); Rabelo et al (2016); Redkva et al (2017); Vaquera et al (2018).
Studies that investigated player-coach relationship using intercorrelation coefficient (ICC)	2	Nogueira et al (2015); Rodríguez-Marroyo et al (2014)
Studies that investigated player-coach relationship using Kappa (k) index	2	Nogueira et al (2014); Nogueira et al (2015)
Studies that investigated player-coach relationship using Mann Whitney	2	Carvalho et al (2018); Imamura et al (1997)

Results

The relationship between rating of intended exertion (RIE) and RPE

Of the twenty-two studies (n= 22) that investigated the intended-perceived relationship, eleven studies (n= 11) measured the association between player and coach and eleven (n= 11) measured the differences in ratings. Of the eleven studies that investigated correlations, seven (n= 7) studies provided interpretation scales for the *r* value (all of which were different) and four (n= 4) did not provide any interpretation scales. These four studies still provided an *r* value though, and an interpretation thereof. Of the seven studies, two (n= 2) reported *strong* correlations with an *r* value of 0.65 (Kraft et al., 2020) and 0.73 (Carvalho et al., 2018) and three (n= 3) studies reported *r* values of 0.58, 0.60, and 0.39 which were classified as *moderate* correlations (Brink et al., 2017; Brink & Frencken, 2018; Scantlebury et al., 2018). Nogueira et al. (2014) reported a Kappa *k* index of 0.64 which classified as 'substantial agreement' between player and coach. In another study, an ICC or 0.80 was classified as a *very high agreement* (Nogueira et al., 2015). There were four (n= 4) studies that did not provide an interpretation scale. Two (n= 2) studies reported *moderately strong* correlations (*r*= 0.84; *r*= 0.75) (Wallace et al., 2009 & Foster, 2001 respectively), Barroso et al (2014) reported a *moderate* correlation (*r*= 0.60), and Brink et al (2014) reported a *weak* correlation (*r*= 0.24). Due to varying interpretations of the r value, the results are misleading if the value is not acknowledged with the interpretation. Further factors should be considered in looking at the relationship between player and coach RPE.

Of the studies that investigated the differences, one (n= 1) study reported no significant differences ($p > 0.05$) between players (mean RPE 5.6 ± 1.5) and that prescribed by coaches (mean RIE 5.8 ± 1.6) (Figueiredo et al., 2019). Two (n= 2) studies (Murphy et al., 2014; Viveiros et al., 2011) reported that the coaches underestimated the session intensity, and in one (n= 1) study the coach overestimated the session intensity in all season periods with a greater discrepancy reported towards the end of the season (Rabelo et al., 2016). One (n= 1) study reported that differences decreased throughout the 3

weeks of beach volleyball training (% Coach x Athlete: first week= 6%; second week= 4% and third week= 2%) (Andrade et al., 2020), and in one study coaches reported overestimating intended RPE in longer repetition distances (Barroso et al., 2015). One (n= 1) study reported that coaches were able to interpret the players' technical and tactical external cues better than physical cues (e.g., sweating and body language) (Macpherson et al., 2019).

Relationship between rating of observed exertion (ROE) and RPE

Nine (n= 9) studies measured the relationship between ROE and RPE. Five (n= 5) studies tested for associations and four (n= 4) studies tested for differences. Of the five studies that tested the association between ROE and RPE, each used a different scale to interpret the *r* value. Kraft et al (2020) reported an *r* value of 0.83 which was considered a *strong* correlation. Two studies reported similar *r* values of 0.63 and 0.64, yet they were interpreted as *large* and *moderate* correlations, respectively (Brink et al., 2017; Scantlebury et al., 2018). Doeven et al (2017) reported an *r* value of 0.25 which was interpreted as a *weak* correlation. Rodriguez-Marroyo et al (2014) reported an *r* value of 0.70 but did not offer an interpretation.

Of the four studies that tested differences between ROE and RPE, one study reported significant ($p< 0.05$) differences (mean ROE 5.4 $\pm$ 1.1; mean RPE 6.2 $\pm$ 1.4) (Murphy et al., 2014) and one (n= 1) reported significant differences in all small sided games (mean differences for 1v1: 1.13; 2v2: 1.72; 3v2: 2.20; $p< 0.0001$) apart from 5v5 (mean difference: 0.63; $p= 0.0019$) (Vaquera et al., 2018). Both studies reported coaches significantly underestimating the session intensity. On the other hand, one study reported coaches overestimating RPE (mean RPE 15.6±2.3; mean ROE 16.1±1.4) with a small effect size (ES= -0.26, CI= -0.48 to -0.04) (Doeven et al., 2017). Macpherson et al (2019) reported agreement between player and coach in only RPE-technical tasks, with players bother overestimating and underestimating RPE-B and RPE-L, respectively.

Categorised session intensities

Ten studies (n= 10) categorised their sessions into low, moderate, and high intensity sessions based on either the RIE or ROE scores. Of the ten studies, nine (n= 9) were categorised based on RIE scores (Barnes, 2017; Brink et al., 2014; Carvalho et al., 2018; Foster, 2001; Nogueira et al., 2014; Rabelo et al., 2016; Scantlebury et al., 2018; Sinnott-O'Connor et al., 2019; Wallace et al., 2009) and one (n= 1) was categorised based on ROE (Kraft et al., 2020)

For intended low/easy intensity sessions, seven (n= 7) studies reported players overestimating the session intensity (Barnes, 2017; Brink et al., 2014; Carvalho et al., 2018; Foster, 2001; Nogueira et al., 2014; Scantlebury et al., 2018; Wallace et al., 2009) and one (n= 1) study reported high agreement (88%) between player and coach (Nogueira et al., 2015). Furthermore, two (n= 2) studies interpreted the relationship as a *small* correlation (r= 0.39 & r= 0.43) (Scantlebury et al., 2018; & Sinnott-O'Connor et al., 2019, respectively).

In intended moderate intensity sessions, three (n= 3) studies reported that the players perceived the session as less intense (Carvalho et al., 2018; Rabelo et al., 2016; Scantlebury et al., 2018), one (n= 1) reported player's perceiving the session as more intense (Brink et al., 2014), and one (n= 1) reported most players (67.8%) having the same perception as the coach (Nogueira et al., 2015). Furthermore, there were interpreted *r* values of *small* (r= 0.27) and *moderate* (r= 0.58) correlations (Scantlebury et al., 2018 & Sinnott-O'Connor et al., 2019, respectively).

For intended high intensity sessions, eight studies reported players underestimating the session intensity (Barnes, 2017; Brink et al., 2014; Imamura et al., 1997; Foster, 2001; Nogueira et al., 2014; Rabelo et al., 2016; Scantlebury et al., 2018; Wallace et al., 2009), and two studies reported high agreement (88%) between player and coach (Nogueira et al., 2015) or having the same perception as the coach (Carvalho et al., 2018). Furthermore, two studies reported *moderate* correlations (r= 0.46 & r= 0.64) (Scantlebury et al., 2018 & Sinnott-O'Connor et al., 2019, respectively).

In observed low intensity sessions, there were reports of both a *large* correlation (*r*= 0.54) (Scantlebury et al., 2018) and reports of coaches overestimating the session intensity (mean RPE 2.9 ± 1.1, mean ROE 3.7 ± 1.9) (Kraft et al., 2020).

For observed moderate intensity sessions, both studies reported players underestimating the session (Kraft et al., 2020; Scantlebury et al., 2018), with one of the studies reporting only *small* correlations (*r*= 0.20) (Scantlebury et al., 2018).

In observed high intensity sessions, Scantlebury et al. (2018) reported a *very large* correlation (mean RPE 4.5 ± 2.1, mean ROE 4.6 ± 1.1, *r*= NR) and Kraft et al. (2020) reported players giving a higher score than the coaches (mean RPE 8.2 ± 0.4, mean ROE 6.5 ± 1.2).

Discussion

The aim of this systematic review was to identify, evaluate, and summarize the outcomes and procedures of studies that assess the relationship between the coach's RIE and/or ROE and that perceived by the player. There are many contributing factors that may have had an influenced on the strength of the relationship, including the type of sport, RPE tool, age and sex of the player, experience and sex of the coach, number of sessions, and phase of the season. These factors will subsequently be discussed.

Which RPE measurement tool is mostly used to measure training load?

The most popular RPE tool used in this systematic review was the Borg CR10 scale (Borg, 1982; Borg, 1998) (n= 9 articles) and the Foster CR10 scale (Foster et al., 2001) (n= 9 articles). Overall, each scale produced equivocal associations or differences, yet the popularity of the scale may suggest that particular scales are more user-friendly or suited to specific environments. For example, Brink & Frencken (2017), utilised the Borg 6 to 20 scale as the Borg CR10 scale resembled the Netherlands school exam grading system and it could lead to ignorance of the lower half of the scale.

sRPE was the most popular in team sports as it takes the player's training duration into account. Multiplying the RPE score by the duration of the session is a more accurate calculation of the internal load placed on the player (Foster et al., 2001). This is especially useful during matches or competitions as players vary playing duration due to substitutions. sRPE, however, tells us little about where the disassociations within the training session originates. In a study conducted by Macpherson et al (2019), disassociations were narrowed down to RPE-B and RPE-L. Agreement was only observed between ROE and RPE for technical tasks; all other coach and player differential-RPE comparisons were deemed not realistically equivalent (Macpherson et al., 2019).

How do training sessions that are categorised by coaches compare to players?

Studies that divided RPE scores into 3 intensity categories (low, moderate, and high intensity) showed large discrepancies between the player and coach. Eleven studies reported players underestimating session intensity whereas eight studies reported players overestimating session intensity. More concerningly, in a study by Barnes et al (2017), cross-country runners rated prescribed easy sessions as significantly harder as the season progressed. This may lead to overtraining and injury as the coach consistently underestimates the session intensity (Foster et al., 2001; Gabbett, 2004). On the other hand, if players are perceiving a training session as less intense than planned, or observed, they are not receiving the necessary stimulus to promote adaptation and risk being underprepared for competition. Brink & Frencken (2018) conducted a study to assess whether the influence of formative feedback to the coach may help strengthen the relationship with players. The agreement between RIE and RPE did not improve between the feedback and non-feedback periods, with the relationship only improving in the intended hard sessions. However, the agreement between ROE and RPE improved in the feedback period. This may suggest that coaches were better able to pick up on subjective cues after the feedback was received, however, it did not influence the following session's prescribed intensity.

Does the type of session influence the player-coach relationship?

Sporting demands can be technical, tactical, and physical and are unique to each player and each sport (Figueiredo et al., 29019; Macpherson et al., 2019, Redkva et al., 2017). Consequently, some studies have investigated the player-coach relationship within these training sessions to determine where the disassociations originate from. Macpherson et al (2019), reported that coaches were able to read the technical and tactical cues (skill execution or tactical positioning) better than physical cues (sweating and body language). This was also the case in a study conducted by (Rodríguez-Marroyo et al., 2014), which reported significant differences between players and coaches in only the physical training sessions ($P< 0.01$). Furthermore, in a study conducted by Andrade et al (2020), there were likely differences shown in only strength (standardised mean difference= 0.43) and physical fitness (standardised mean difference= 0.40) and not tactical-technical training sessions. This could be the result of the players being unmotivated to perform this type of training as opposed to matches or technical-tactical training thereby giving an overestimated RPE score (Rodríguez-Marroyo et al., 2014). Furthermore, it has been suggested that players find sport-specific conditioning tasks less intense than generic conditioning sessions even if they are the same duration and/or demand the same intensity (Hill-Haas et al., 2009). Another reason for the disassociation in physical sessions is that often the fitness sessions are conducted by the conditioning coach and not attended to by the tactical/technical coach. Therefore, they do not pick-up on the exertional cues as attentively as they would during their own sessions.

Does the type of sport influence the ability for coaches to be fully vigilant during a session?

Fifteen articles assessed the player-coach relationship in team sports including rugby union, hockey, beach volleyball, volleyball, soccer, basketball, futsal, and netball. Ten articles assessed the relationship in individual sports including swimming, judo, karate, cross country running, middle- and long-distance running, and tennis. Typically, team sports require more vigilance and observation from a coach due to the number of players (Scantlebury et al., 2018). In individual sports, it is easier for the

coach to observe and prescribe workloads (distance and/or duration) in a well-informed manner as it is easier to track the session. However, this is not always the case. Individual sports could still involve more than one player per one coach. The study with the highest ratio of players to coaches (17.7 to 1) was conducted by (Barroso et al., 2014) and reported associations over 3 age groups in swimming. Agreement between coaches and swimmers increased with age and experience with the youngest age group reporting a correlation of r= 0.31 (P< 0.001) and the oldest age-group reporting a correlation of r= 0.74 (P< 0.001) (Barroso et al., 2014). A study with the lowest ratio of players to coach (0.5 to 1) was conducted by Andrade et al (2020) and reported that coach and beach volleyball player's RPE differences decreased during the 3 weeks of training in all three session types (physical, strength and tactical-technical). This may suggest that while the ratio of players to coaches can play a role, the relationship can still progress, and differences can diminish as the season advances.

How does the phase of the season influence the coach's perception of exertion?

In the beginning of a season (pre-season), players present impoverished fitness capacities and varying skill levels compared to subsequent phases in the season (Andrade et al., 2020). Further along in the season, players adapt to the training stimuli and their physical condition and skill level improve. This was the case in a study, conducted by Andrade et al (2020), which found that differences between beach volleyball players and their coaches decreased during the 3 weeks of training. The study goes on further to suggest that coaches overestimated the players physical condition and as the players improved and established similar fitness capabilities, the differences diminished (Andrade et al., 2020). On the other hand, Nogueira et al (2015) conducted a study that observed the relationship over two phases in the season. During the transformation phase (phase 1), that included a higher training load volume compared to the taper phase, there was a significant and high-level correlation (ICC = 0.79, p= 0.001). However, during the taper phase (phase 2), players generally underestimated the intended session intensity and there was a significant and low-level correlation (ICC = 0.19, p= 0.001). This implies that even at the end of the season where coaches are familiar with the players fitness and

skill capacities, there may still be discrepancies. Rabelo et al (2016) also reported a greater discrepancy between the coach's RIE and Futsal players' RPE toward the end of a 4 phase (preseason, comp, inter-comp, and comp-2) season. This draws attention to the impact of the period of the season in which data are collected and its possible impact on the relationship between player and coach. Coaches need to consider being more vigilant when observing or prescribing sessions in certain phases of the season especially within the first few weeks of training when players vary in fitness capabilities and towards the end of the season during the competition phase.

How does the sex of the player and coach play a role?

Two articles investigated female players, six articles investigated male players, while 10 articles did not disclose the sex of the players. In the seven studies that assessed both males and females, only two studies reported results that compared the sexes. In a study conducted by Barnes (2017) where both female and male cross-country runners RPE scores were compared to the coaches, both sexes reported a higher intensity than the coach for both easy and moderate intended sessions. There was no difference between male runners and the coach for intended hard sessions, but females reported significantly lower scores (Barnes., 2017). Furthermore, Kraft et al (2020) investigated both male and female basketball players with their respective coaches. The coach and female players RPE had a higher correlation for RIE (r= 0.71), and ROE (r= 0.60) compared to the male basketball players and their respective coaches (r= 0.42 and r= 0.48 respectively). However, the results are questionable to compare as each team had a separate coach. One article also suggested that the difference in the observers' (male) and players' (female) sex may have had an influence on the players' sRPE (Rodríguez-Marroyo et al., 2014). Boutcher et al (1988) suggested that both audience and self-constructional aspects of self-presentation can affect RPE. Some players (more so males) may give lower RPEs in the presence of a female coach (or experimenter) especially at moderate and high work intensities. While the sex of the coach is suggested to be an influential factor, no study has investigated the influence of the coach's sex on the relationship between players' and coaches' perception of effort.

Does the age and experience of the player and coach influence the relationship?

Studies reported correlations between player and coach strengthening with the age and experience of players, suggesting it to be an important contributing factor (Barroso et al., 2014; Brink et al., 2014). Brink et al (2017) suggested that coaches base their predicted and observed RPE ratings on their previous experiences of the player's response. Thus, it is important that the coach and player are familiar with the tool as well as with one another. In one study that did assess the coach's experience, it found that both expert and beginner coaches had a similar relationship with the player. However, caution is urged in interpreting this result as many studies did not report the coach's experience in years, or their familiarity with the RPE tool.

Furthermore, Barroso et al (2014) reported that the youngest age-group of swimmers (11-12 years old) had the lowest correlation of $r = 0.31$ ($p < 0.001$) and their RPE scores differed from the coaches in 3 intensity categories (low, moderate, and high). The 13–14-year-old age category reported an r value of 0.50 ($p < 0.001$) and the oldest age-group (15-16 years old) reported an r value of 0.74 ($p < 0.001$). This may suggest that the more mature a player is within a sport, the better able they are to identify prescribed intensity levels.

On the other hand, little has been reported on the effect of the coach's experience on the relationship between player and coach. Previously, it was thought that the more familiar a coach is with individual players, a team, an age-group, or load monitoring tools, the more likely a coach will be able to pick up on subjective cues thereby improving the association. However, Rodríguez-Marroyo and colleagues (2014) reported in their study that both beginner and expert coaches had a similar interpretation and prediction of the players' RPE (expert coach, $r = 0.75$; beginner coach, $r = 0.76$) and the two coaches scores were strongly correlated ($r = 0.90$). This proposes that experience in coaching a particular sport or age-group may not directly affect the coach's ability to perceive a player's subjective response.

Does the number of sessions impact the relationship and do disassociations become more or less apparent?

In this systematic review, the number of sessions investigated within the studies ranged from 4 sessions to 3024 sessions. While many studies did not report the coach's familiarity with using the RPE tool it is apparent that the more sessions that take place in the study, the more familiar a coach will be with using the RPE measurement tool. However, studies investigating as much as 3024 sessions reported that cross country runners perceived training closer to the moderate intensity throughout the season, regardless of the intended session intensity. The study that investigated the relationship over 4 sessions reported dissociations with coaches both over- and under-estimating session intensity (Barroso et al., 2015; Imamura et al., 1997; Viveiros et al., 2011). This proves that dissociations can occur in as little as 4 sessions and can still be apparent in as many as 3024 sessions. Careful steps to rectify disassociations need to be taken early in the season to avoid maladaptation.

Conclusion

RPE is a popular internal load monitoring tool, however the coach's perception of intensity is not always in agreement with the players. Through the synthesis of included articles, twelve (n= 12) studies reported players overestimating the session intensity and eleven (n= 11) studies reported players underestimating the session intensity in at least one or more training comparators. Possible factors that may contribute to this disagreement include sex, age, experience of the player; the RPE tool; the type of sport; the coach's experience; the type of session; and the phase of the season.

Both the intended-perceived and the observed-perceived relationships showed disagreements. This suggests that one is not more important to collect than the other and the two should be used in conjunction to see if the training session is reaching (ROE) the planned session intensity (RIE) and if the players are achieving those intensities (RPE). Practitioners should aim to control or manage factors that may influence the player's reported perceived exertion, thereby equipping themselves with the ability to better interpret and monitor training load.

Limitations

The main limitation was the under reporting of study characteristics. Many studies did not report the experience of the coach and their familiarization with the RPE measurement tool. Furthermore, a few studies reported how many weeks the teams were observed but not the number of training sessions. There was also underreporting of raw data (mean values) making it difficult to compare studies using visual representations such as graphs. Study designs, which were also largely underreported, differed between studies. In some studies researchers set out the training session components and comparators (duration, distance, speed etc.) making the study design experimental, whereas other studies had a more observational approach and did not interfere with the training programs or planning. A few studies confused the terms sRPE and training load by referring to the sRPE (Foster et al., 2001) as the training load when it is only referred to as such once multiplied by the session duration (sRPE x session duration). Another limitation of the review was that only one author performed the data extraction as well as the study quality assessment. In future, at least two authors should perform the data extraction and study-quality assessment for best practice (Shea et al., 2017).

Another limitation, and finding thereof, was that studies presented different interpretation scales for the associations (*r* values). Where one study would classify *r*= 0.64 as a *weak* correlation, another article would interpret it as a *moderate* correlation. This can become concerning when the results are discussed without the *r* value present. There were also studies that included statistics but no interpretation as well as one study that misinterpreted the r value according to the table provided within the study (Scantlebury et al., 2018). Studies also lacked in statistical reporting where results were concluded with no values present (only graphs). Lastly, there were a limited number of studies that reported differences with the correlations. Highly correlated scores were hard to interpret since correlations can be perfect even though the scores are very different, as correlation measures the relationship. Equivalence testing would have shown if the player's and coach's scores were the same and not consistently different.

Chapter 3

USING THE RATING OF PERCEIVED CHALLENGE (RPC) AS TECHNICAL SKILL MONITORING TOOL IN TEAM SPORTS

Introduction

Skill training is not periodised and monitored to the same extent as physical training (Farrow & Robertson, 2017). If the goal of monitoring physical training is to ensure players adapt positively to the training stimulus and are physically prepared for competition, the goal of monitoring skill training should be to optimise skill learning, adaptation, and transfer to competition (Farrow & Robertson, 2017; Otte et al., 2019). When monitoring physical training, both the amount of work performed (external load) and the player's response to the work (internal load) are recorded (Borresen & Lambert, 2009; Soligard et al., 2016). The monitoring of skill training, on the other hand, is usually limited to capturing training time, training frequency, and movement repetitions (Farrow & Robertson, 2017; Hendricks et al., 2019).

A simple, inexpensive, and quick method to quantify players' global experience of the physical workload is to ask the player to rate how hard the training bout was on a category ratio rating scale from 0 – 10, where 0 represents rest and 10 maximal effort (Foster et al., 2001; Haddad et al., 2017; Lambert & Borresen, 2010; Otte et al., 2019). This measurement is known as the session rating of perceived exertion (sRPE) (Foster et al., 2001; Haddad et al., 2017; Lambert & Hendricks, 2012; Otte et al., 2019). Weston and colleagues however recognised that a global rating of training may not be sensitive enough for the range of training modalities within team sports (Weston et al., 2015; McLaren et al., 2017; McLaren et al., 2016). In response, they proposed that the sRPE be differentiated into breathlessness (RPE-B), leg (RPE-L), and technical (RPE-T) (Weston et al., 2015; McLaren et al., 2017; McLaren et al., 2016). From a technical skill training perspective, the RPE-T is a step in the right direction. However, the instructions and anchors still represent physical intensities. As such, the RPE-T arguably characterises how physically hard the technical skill session was, and not necessarily the technical demand of the skills performed during the session.

Technique is the ability to perform a task (e.g., tackle) and skill is the ability to perform that task in an unstructured, highly representative environment, such as a match (Hendricks et al., 2018). A skill

session comprises of drills in which technique is practiced to ensure appropriate skill learning and transference to matches. To quantify the technical demand of a skills session and complement session sRPE ratings, Hendricks et al. (2019) proposed the rating of perceived challenge (RPC) (Hendricks et al., 2018; Hendricks et al., 2019). The RPC is based on skill acquisition theories and frameworks and therefore has technical skill-specific instructions and anchors (Davids et al., 2008; Farrow & Robertson, 2017; Guadagnoli & Lee, 2004). Instead of asking players how hard a training session was, players are asked to rate how technically challenging the session was on a 0 – 10 scale. In theory, the technical challenge of a session can be determined by the difficulty of the task and information available to the player (Guadagnoli & Lee, 2004). The difficulty of the task and the amount of information available to the player is typically set by the coach or trainer, with the aim of creating the optimum challenge to ensure skill learning and transfer (Hendricks et al., 2019). Since proposed, the RPC has been recognised as a potential skill load measurement for skill periodization (Otte et al., 2019), coaching for long-term athlete development (Till et al., 2021), injury prevention training (Walker et al., 2021), and returning athletes to play after injury (Geldenhuys et al., 2021; Stokes et al., 2020). The RPC should be used in conjunction with other internal load measurement tools (e.g., RPE), as well as objective measures (e.g., repetitions and speed) (Hendrick et al., 2019). However, the relationship between RPE and RPC is unknown. Sessions that involve match scenarios may contribute to a higher RPC as well as a higher RPE. Whereas sessions that involve a high level of physical activity but not technical or tactical drills (e.g., gym or conditioning sessions) may warrant a low RPC but high RPE.

Using sRPE, studies within team sports have shown a mismatch between coach and player perceptions of training (Brink et al., 2014; Macpherson et al., 2019; Paul et al., 2021; Scantlebury et al., 2018). Coaches both underestimate and overestimate players' perceived ratings of the session intensity (Brink et al., 2014; Macpherson et al., 2019; Paul et al., 2021; Scantlebury et al., 2018). Interestingly, an exploratory study using differential RPE to monitor one team over seven consecutive training sessions found RPE-T to be the only rating that was likely to be equivalent between the players and coach (Macpherson et al., 2019). Studies on the relationship between player and coach perception of

training have mainly focused on non-collision-based sports such as football (Brink et al., 2014; Macpherson et al., 2019; Paul et al., 2021). Rugby union is a highly physical-technical demanding collision-based team sport, that is popular across the globe. In rugby union, for the most part, coaches are responsible for the technical preparation of players. Given the growing need to periodise and monitor skill training (Farrow & Robertson, 2017; Hendricks et al., 2018; Otte et al., 2019), understanding the relationship between coach and player ratings for the perceived technical challenge of training sessions will be a timely contribution to the literature and may advance practice.

A lot has been said about the negative impact that a player-coach mismatch may have with regards to RPE. But little is known of the negative impact a RPC mismatch may bring. Hendricks and colleagues (2018) proposed a tackle skill training framework which is designed to monitor tackle training. The Framework was designed with the goal of improving tackle performance while reducing players' risk of injury (Hendricks et al., 2018). By altering the task difficulty and information available, and interpretable, by the player, different levels within the framework are set. To determine the rate that the player progresses, coaches need to observe and assess the player (in real-time or on video). This observation and assessment can determine whether the player has reached their optimal challenge point (Hendrick et al., 2018). Furthermore, the player should also give a RPC score for the skill session. A mismatch between player RPC and coach observed-RPC will lead to an early or late progression. Early progression could result in injury as the player has not played in such technically and physically demanding conditions (Hendricks et al., 2018). Whereas a late progression or suboptimal challenge point could hinder the development of the player leading to underperformance.

Therefore, the purpose of this study was to determine the relationship between player and coach RPC for different training sessions over a competitive rugby union season. Also, considering that RPC intends to complement sRPE, a secondary aim was to explore the relationship between player RPC and sRPE.

Subjects

Using an observational longitudinal study design, four (n= 4) male coaches and fifty-one (n= 51) male elite under 21 (U21) rugby union players (mean ± SD) (height, 184 ± 0.1cm; weight 94.94 ± 13.34kg), which included twenty-five forwards and twenty-six backs, were monitored over an 11-week competitive South African Rugby U21 championship season (South Africa's annual premier U21 domestic rugby union competition). The data was collected from one team and took place in the in-season period (during competition). This equated to 66 training days and a total of 1798 training session observations. All participating players provided consent to have their training data collected, stored, and analysed for research purposes and the study was approved by the University's Human Research Ethics committee (HREC REF 171/2021) (Appendix F).

Methods

At the start of the season, an information session was held to explain the purpose of the study and how RPE and RPC are determined. Furthermore, there was a trial week where the players and coaches could familiarise themselves with the RPC and sRPE scales in a practical setting. None of the players or coaches had prior knowledge of the importance or reasoning for providing RPE and none of the coaches or players were familiar with either of the scales prior to the session. In particular, the purpose and anchors of each scale. During the season, immediately after (between 15-30 minutes) each training session, players were asked, privately, to indicate their RPC and sRPC, and coaches were asked to provide a single RPC score based on their observation of the training session. Players and coaches were allowed to give the scores verbally or by pointing to a number on the visual RPE and RPC scales (that consisted of verbal anchors). Player RPC and sRPE ratings were collected after team sessions (a technical field-based session with all players training together), split sessions (technical field-based session where players trained separately according to their positional grouping (forward and backs)) and gym sessions (non-technical, non-field-based session with all players training together). Coach RPC ratings were only collected after team sessions and split sessions.

Statistical analysis

As the data are ordinal, non-parametric statistical methods were used to analyse the data. The Spearman's Rank correlation coefficient (rho) was used to determine the relationship between player RPC and coach RPC, and player RPC and player sRPE. Associations were tested over the 11-week period, by session type (team, split and gym), and by playing position (forwards and backs). The significance level was set at 0.05. The strength of the relationship was determined using the standard correlation coefficient interpretation scale where 0 = no relationship, 0.1 – 0.3 = *weak,* 0.4 – 0.6 = *moderate*, 0.7 – 0.9 = *strong*, and 1 = *perfect* (Dancey et al., 2004). The Mann-Whitney test was used to test for differences in player RPC, sRPE and coach RPC between forwards and backs within each session, with the significance level set at 0.05. Means ± Standard deviation (SD) in arbitrary units (AU) are reported for all data. Statistical analyses were conducted using R (R Core Team, 2017) and Prism V.9 (GraphPad, San Diego, California, USA) and figures were produced using R (R Core Team, 2017).

Results

A *weak positive* relationship (rho= 0.30; $p<0.01$) was found between player RPC (4.30 ± 1.60 AU) and coach RPC (4.95 ± 1.32) for team sessions, while a *moderate positive* relationship (rho= 0.47; $p< 0.05$) was found for split sessions (player RPC 4.32 ± 1.84 AU; coach RPC 4.19 ± 1.49 AU) (Figure 5).

A *moderate positive* relationship (rho= 0.67; $p< 0.05$) was found between player RPC (4.32 ± 1.84 AU) and player sRPE (4.57 ± 1.59 AU) for split sessions, as well as for team sessions (RPC 4.95 ± 1.32 AU; sRPE 5.53 ± 1.51 AU; rho= 0.47; $p< 0.01$) (Figure 5). No relationship (rho= 0.06; $p> 0.05$) was found between player RPC and sRPE for gym sessions (RPC 3.45 ± 1.28 AU; sRPE 5.23 ± 1.11 AU).

Forwards reported a higher RPC (5.32 ± 1.58 AU) compared to backs (3.35 ± 1.53 AU) for split ($p<0.0001$) and team sessions (forward's RPC 4.83 ± 1.49 AU; backs RPC 3.71 ± 1.52 AU; $p< 0.0001$) (Table 6). Forwards also reported a higher sRPE for split sessions (forwards sRPE 5.43 ± 1.29 AU; backs sRPE 3.72 ± 1.39 AU; $p< 0.0001$) and team sessions (forwards sRPE 5.77 ± 1.46 AU; backs sRPE 5.25 ±

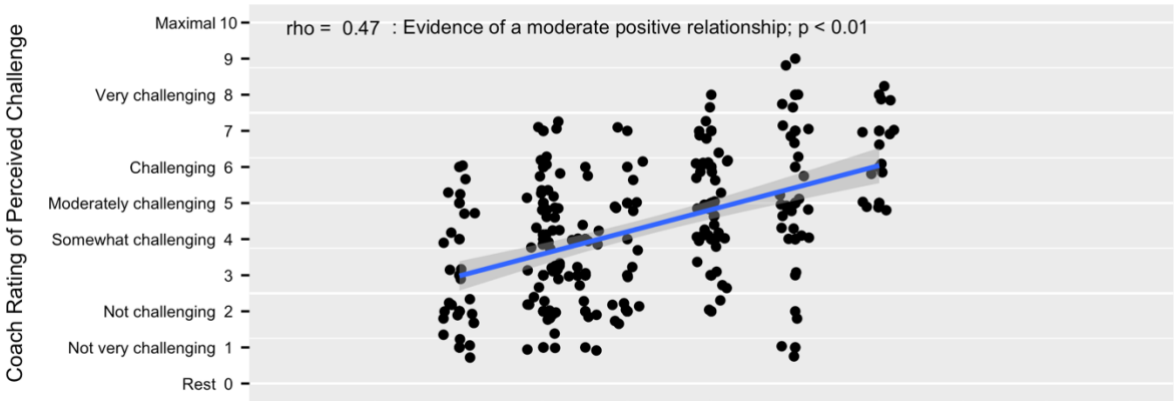
1.52 AU; $p<0.0001$). No differences in RPC and sRPE between forwards and backs were found for gym sessions ($p> 0.05$). For split sessions, coaches reported higher RPC ratings for forwards (forwards coach RPC 5.15 ± 1.31 AU; backs coach RPC 3.27 ± 0.96 AU; $p< 0.0001$), while during team sessions, coach RPC ratings were similar between the postional groupings (forwards coach RPC 4.90 ± 1.33 AU; backs coach RPC 4.99 ± 1.31 AU; $p> 0.05$).

Table 7. Player Rating of Perceived Challenge (RPC), Player session Rating of Perceived Exertion (sRPE) and coach RPC, and the strength of their relationships for each type of training session. Data are shown as mean ± standard deviation (SD) in arbitrary units (AU) and Spearman Rank correlations coefficients (rho).

		Player RPC	**Coach RPC**	**Player sRPE**	**Coach RPC vs Player RPC**		**Player RPC vs Player sRPE**	
		Mean ± SD (AU)	*Mean ± SD (AU)*	*Mean ± SD (AU)*	*rho*	*Interpretation*	*rho*	*Interpretation*
Split	*Overall*	4.32 ± 1.84	4.19 ± 1.49	4.57 ± 1.59	0.47*	*Moderate*	0.67*	*Moderate*
	Backs	3.35 ± 1.53	3.27 ± 0.96	3.72 ± 1.39	0.28**	*Weak*	0.52**	*Moderate*
	Forwards	5.32 ± 1.58^	5.15 ± 1.31^	5.43 ± 1.29^	0.23*	*Weak*	0.2*	*Weak*
Team	*Overall*	4.30 ± 1.60	4.95 ± 1.32	5.53 ± 1.51	0.30**	*Weak*	0.47**	*Moderate*
	Backs	3.71 ± 1.52	4.99 ± 1.31	5.25 ± 1.52	0.30**	*Weak*	0.41**	*Moderate*
	Forwards	4.83 ± 1.49^	4.90 ± 1.33	5.77 ± 1.46^	0.36**	*Weak*	0.47**	*Moderate*
Gym	*Overall*	3.45 ± 1.28		5.23 ± 1.11			0.06**	*Weak*
	Backs	3.38 ± 1.34		5.26 ± 1.04			0.14**	*Weak*
	Forwards	3.51 ± 1.20		5.20 ± 1.17			-0.02	*No relationship*

* = $p < 0.05$; ** = $p < 0.01$. Spearman Rank correlations (rho) coefficients interpretations: 0 = no relationship, 0.1 - 0.3 = *weak*, 0.4 - 0.6 = *moderate*, 0.7 - 0,9 = *strong*, and 1 = *perfect*. ^ = significantly higher than backs ($p < 0.0001$)

A) Team Sessions



B) Split Sessions

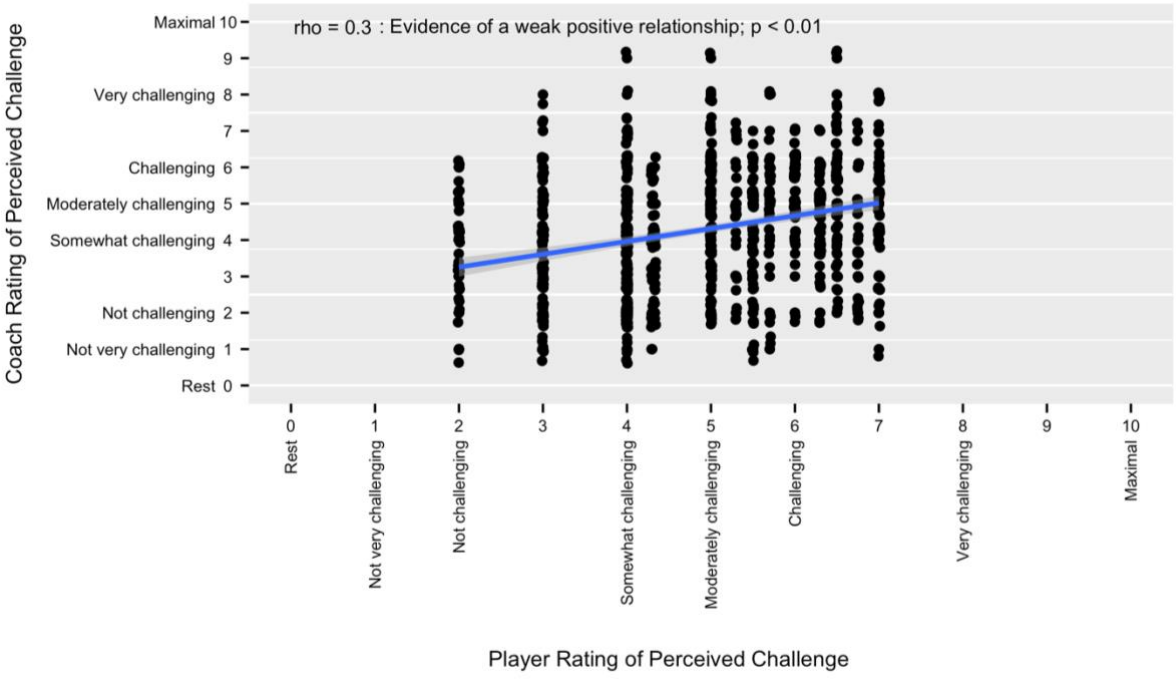


Figure 5: Relationship between Player Rating of Perceived Challenge and Coach Rating of Perceived Challenge for A) Split Sessions and B) Team Sessions. Spearman Rank correlations coefficients (rho) and strength of relationship also shown.

Discussion

This is the first study to use the RPC to monitor technical skill load in a team setting and test its relationship to coach RPC and player sRPE. Our data showed the strength of the RPC association between the player and coach was dependent on the type of session, with a stronger relationship for split sessions. During split sessions, coaches are working with fewer players, and focusing on position-specific technical outcomes. During team sessions coaches are working with a large group of players, making it difficult to focus on individual player skills. The average overall player and coach RPC rating for split sessions were perceived as '*somewhat challenging'*, which indicates sessions were moderately representative of competition (Hendricks et al., 2019). Recently, Otte et al. (2019) described a skill training periodization framework for 'specialist coaches' i.e., coaches that work with players on a one-one basis or in small groups. The skill training periodization framework outlines three connected training stages based on the level of competition representativeness and perceived task complexity – namely, i) coordination training (exploring coordinated movements within an emerging training environment), ii) skill adaptability (focusing on skill learning, adaptability, and robustness), iii) performance training (focusing on match performance outcomes, and less on skill development). The first two stages largely operate in a moderate representative training environment with small player groups, while the performance training stage is typically completed in a high representative training environment involving the entire team (Otte et al., 2019). Plausibly, the first two training stages in the skill training periodization framework are comparable to the split sessions in the current study, while the performance training stage is comparable to team sessions. While Otte et al. (2019) suggested the RPC be used as a potential internal skill load measurement for monitoring player's progression through the framework, the current data suggests that the player-coach agreement may be higher in the skill development focused stages (coordination training and skill adaptability). Stronger associations between the player and coach have also been reported when capturing the sRPE in smaller groups (compared to entire teams), implying that working with fewer athletes allows the coach to be more aware and attentive to the workload completed during the session (Brink et al.,

2014; Scantlebury et al., 2018). This may have also been the case when capturing the RPC in split sessions.

The RPC is intended to compliment internal physical load measurements such as the sRPE (Hendricks et al., 2019). The *moderate positive* relationship during team sessions, and the *moderate* relationship for split sessions suggest that there is an interaction between the two perceptual constructs. This is not surprising considering that the spilt and team sessions had both a technical and physical component. The value of differentiating perceptual constructs during training has been highlighted before (Macpherson et al., 2019; McLaren et al., 2017; McLaren et al., 2016), and considering that RPC and sRPE have separate monitoring purposes (RPC – skill learning/adaptability and transfer; sRPE – physical adaptation), the recommendation to capture RPC (along with sRPE) during skills sessions may be justifiable. Gym sessions were focused on players' physical conditioning and were not highly challenging of players technical skills. As a result, no relationship between RPC and sRPE was found for gym sessions. This finding is encouraging in terms of the RPC's construct validity. To build on the current work though, experimental studies where players perform tasks with a pre-determined RPC and RPE may be required.

Within the split and team sessions, forwards reported higher RPC ratings than backs, while similar RPC ratings were recorded for gym sessions. During training, in addition to the general skills required by all positions (passing, tackling, ball-carrying, rucking), forwards practice techniques required for the scrum, line-out and maul (Campbell et al., 2017). These contact events are highly technical, and forwards require specific technique training to participate in them safely and effectively (Hendricks et al., 2017). The higher RPC ratings reported by forwards within the split and team sessions likely represent these additional technical demands and offers further support for the construct validity of the RPC. However, these additional technical demands experienced by forwards in team and split sessions were not perceived by the coaches. Further investigation into the differences in perception are required.

Limitations

A key strength of the current study is that it was conducted within in a team setting over a full season. However, this applied research design had limitations. A noteworthy one is the absence of an external measure(s) to objectively describe the technical skill demands of the training sessions. Currently, objective external measures of technical skills training in rugby union are not well described and are limited to estimates such as movement repetitions. In the context of the current study, objective external measures may have added another dimension to the interpretability of our findings. Other potential approaches to objectively describe the technical skill demands of training sessions are using video analysis and systematic observation (Cope et al., 2017; Hendricks et al., 2020). To use these methods effectively though, a framework of training descriptors and definitions need to be developed for rugby union, similar to the framework for analysing matches (Hendricks et al., 2020). Recently, Dalton-Barron et al. showed that sRPE is influenced by contextual factors such as the length of the recovery period between matches and the outcome of the previous match (Dalton-Barron et al., 2021). Specifically, higher sRPE's were reported for longer recovery cycles and when losing the previous match. This suggests similar contextual factors and potentially others (for example, technical performance within matches) will also influence RPC ratings.

Another noteworthy limitation is that is it unknown whether players and coaches accurately perceive the challenge of an entire session. There is a possibility that coaches and players are basing their subjective ratings on specific drills within the session. In contrast to sRPE, where players have a general sense of physical fatigue after a session, RPC has not yet been collected after a training session until now. Further investigation, in a controlled environment, into whether RPC can be based across several technical and tactical drills is needed to determine if a session RPC is valid and reliable.

Furthermore, the collection of a coach's rating of intended challenge would have strengthened the study and could have been compared with ROC to determine if the intended technical skill session achieved what was intended.

Lastly, because the data contained more than two repeated measures per individual, and the Spearman's rank correlation test cannot account for more than two observations, it was not an appropriate test. The Spearman's rank correlation test statistic is based on ranking the differences between two observations per individual. Therefore, a repeated measures correlation coefficient would have been more suitable. In conclusion, this is the first study to use the RPC technical skill measurement in a team setting and test its relationship to coach RPC and player sRPE. The strength of the RPC association between the player and coach was dependent on the type of session, with a stronger relationship for split sessions. Player-coach agreement may be higher in the skill development focused stages, such as coordination training and skill adaptability, where coaches are working with fewer players, and focused on specific technical outcomes. A relationship between RPC and sRPE was found for field sessions, but not for gym sessions. Also, forwards reported higher RPC ratings during field sessions, which likely represents their additional technical training from scrums, line-outs and mauls. These findings offer insight into construct validity of the RPC.

Chapter 4

CONCLUSION AND PRACTICAL APPLICATION

Key findings and summary

The purpose of this thesis was to identify, evaluate, and summarize the outcomes and procedures of studies that assess the relationship between the coach's RIE and/or ROE and the players' RPE through a systematic review. Secondly, the thesis aimed to determine the relationship between player and coach RPC for different training sessions over a competitive rugby union season as well as explore the relationship between player RPC and sRPE.

This thesis found the strength of the relationship between player and coach RPE to have many contributing factors. Based on the conclusions, practitioners should be aware of impactful factors such as the familiarisation with the RPE tool, the age (or level of experience) and sex of the players, the experience and sex of the coach, the season period, the type of activity, and the protocols used to collect RPE. Controlling and awareness of such contributing factors may result in a stronger association or reduced differences between the player and coach. This is important as continuous disassociation can lead to increased injury risk and/or underperformance. Through this awareness of load, coaches and practitioners can alter future training sessions with the aim of regulating the overall training load. Although it is known that inappropriate training loads can lead to injury and underperformance, the implications that the relationship between the player and the coach might have on the player's performance needs further research.

In line with the systematic review, the relationship between player RPC and coach RPC was dependent on the type of session, with a stronger relationship found for split sessions. During the split sessions, coaches were observing less players and therefore were more capable of observing subjective cues. RPC may be more meaningful in the skill development-focused stages where there is more focus on specific technical outcomes. Comparing player RPC ratings to other players within the team may help coaches and practitioners to identify players that need more technical or tactical guidance. Furthermore, coaches can identify which sessions players may be finding more technically challenging.

It is important to know the strength of the relationship between player and coach to determine if players are receiving the load needed to successfully adapt and improve performance. It is also important to know if the prescribed training loads are being successfully carried out on the field. Inability to reach training objectives will result in underperformance and consistent overtraining will result in injury.

sRPE and player RPC are both internal load monitoring tools where one method measures the perceived exertion of the players, and the other measure how technically challenged the player was in the session. The RPC is intended to compliment internal physical load measurements such as the sRPE (Hendricks et al., 2019) and so how these two measurements interact is important to determine the functionality of RPC in technical-tactical sessions. This thesis confirmed that there is an interaction between the two perceptual constructs due to field sessions being both physical and technical in nature with *moderate* correlations found in both. The gym sessions are predominantly physical in nature, with little technical skill needed from the player. Consequently, there was no relationship found between player RPC and sRPE for gym sessions, which helps strengthen the construct validity of the RPC. Furthermore, their differences show that the two have separate monitoring purposes and that capturing RPC together with sRPE during skill sessions is advised.

Future directions and practical applications

As previously stated, monitoring training has become more popular due to immediate feedback on the player's physiological and perceptual responses (Foster et al., 2017). This immediate feedback could be something as simple as using RPE. However, this should be used in conjunction with other monitoring systems such as GPS to get a holistic perception of the load placed on the player. Monitoring training load is important to highlight these disassociations and gives thorough insight into the actual load placed on players. Coaches can use this information to alter future training sessions if need be. Although all these RPE scales may be proven valid and reliable, it may not be suited to a specific environment. For example, the sRPE is more suited to a team environment compared to Borg

CR10. Therefore, coaches and practitioners need to take the environment and certain contributing factors into account when choosing an RPE measurement tool and the protocol used to collect it.

This study can assist coaches in monitoring the skill load in rugby and offer a new dimension to internal load monitoring. However, further research needs to be done to confirm the usability of the RPC in individual sports and other team sports. Experimental studies where players perform tasks with a pre-determined RPC and sRPE ratings, and observational studies using video analysis and systematic observation to objectively describe the technical skill demands of training sessions are also required to further support the construct validity of the RPC.

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Appendices

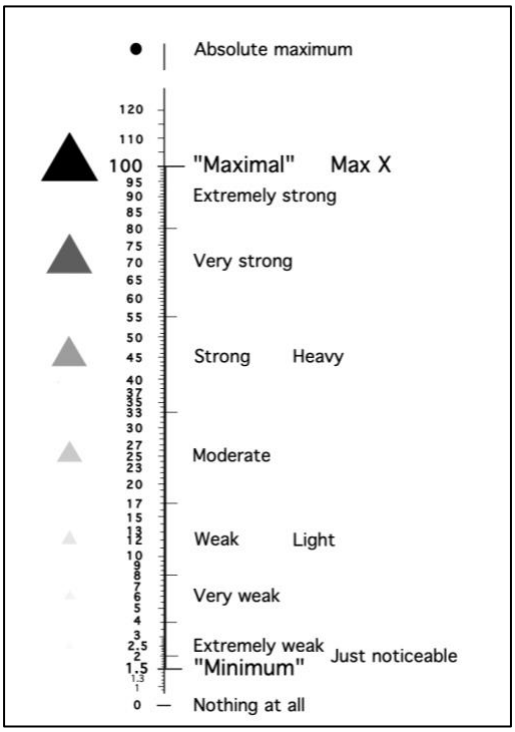
Appendix A: Borg 6-20 Scale

6	No exertion at all
7	Extremely Light
8	
9	Very Light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Appendix B: The Borg CR10 Scale

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	“maximal”
11		
●	Absolute maximum	Highest possible

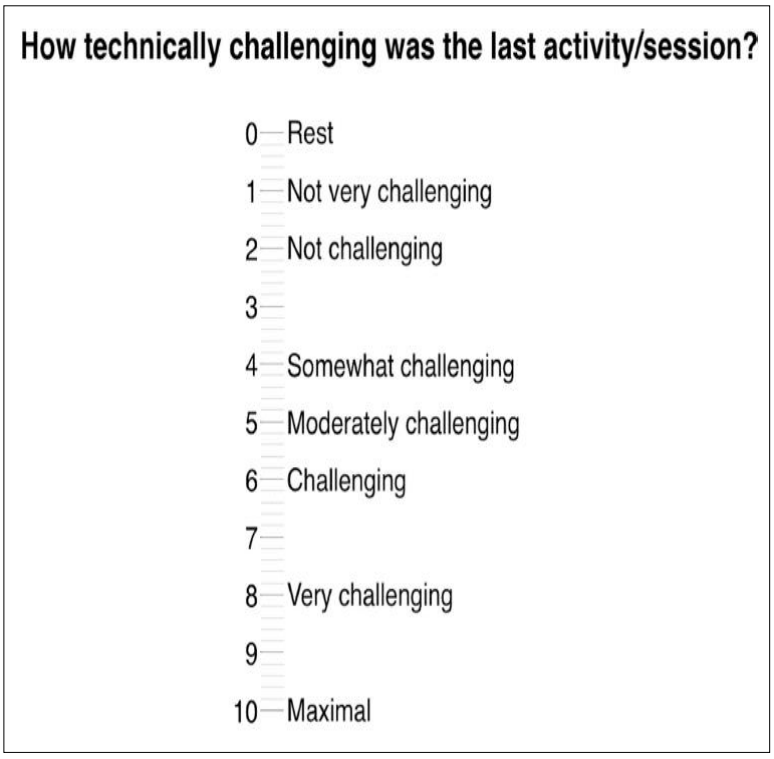
Appendix C: The Borg centiMax® scale (CR100)



Appendix D: Foster et al. (2001) CR10 Scale

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

Appendix E: RPC Scale



Appendix F: Ethics Approval

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room G50- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

24 March 2021

HREC REF: 171/2021

Dr S Hendricks
ESSM
Human Biology
Email: jennabam96@gmail.com

Dear Dr Hendricks

PROJECT TITLE: THE RELATIONSHIP BETWEEN PLAYERS' AND COACHES' PERCEIVED CHALLENGE OF TRAINING-MSC CANDIDATE-MISS JENNA BAM -SUB-STUDY LINKED TO R011/2017

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19, dated 17 March 2020 & 06 July 2020.

Approval is granted for one year until the 30 March 2022.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF 171/2021 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

HREC/REF 171/2021sa

NHREC-registration number: REC-210208-007

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use: Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

HREC/REF 171/2021sa