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Difference of perceived effort index in reserve as a self-regulation method compared to objective effort methods: a systematic review.

Diferencia del índice de esfuerzo percibido en reserva como método de autorregulación en comparación con los métodos de esfuerzo objetivo: una revisión sistemática

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Abstract. The use of rate of perceived effort scales (RPE) based on reserve repetitions (RIR) can be a complement to absolute methods, such as 1 maximum repetition (1RM), the percentage variable with respect to 1RM (xRM), and the average concentric velocity (ACV), optimizing control of training intensity. This study aimed to evaluate the validity of using a subjective RPE-RIR effort scale as a self-regulation tool with respect to quantifying the intensity of the training load. We perform a systematic search in PubMed, WOS, and Scopus databases. 2,271 articles were reviewed, of which 7 met the eligibility criteria. These studies involved 147 subjects trained in strength (novices, experienced professionals, and powerlifters), who responded to the implementation of protocols that quantify the subjective and objective load intensity (RPE-RIR relationship and objective load intensity, mean speed - 1RM/xRM). There are strong correlations between the variables in the RPE-RIR study/ Average concentric velocity (r = 0.90 - 0.92; r = -0,98 to -1,00; EL: r = 0.85/ r = -0.88, NL: r = 0.85/ r = -0.77), RPE-RIR/1RM (r = 0.88 to 0.91). The main conclusions of this systematic review regarding methods and means of quantifying objective and subjective intensity of training load indicate a strong correlation between RPE-RIR (as a subjective method) and ACV and 1RM/xRM (as an objective method), especially in inexperienced populations. However, these findings should be considered individually, given the differences between protocols and movements analyzed and the limited analysis of novice populations.
Keywords: Subjective Effort, Training Load, Exercise Methodologies.

Resumen. El uso de escalas de tasa de esfuerzo percibido (RPE) basadas en repeticiones de reserva (RIR) puede ser un complemento a los métodos absolutos, como 1 repetición máxima (1RM), la variable porcentual con respecto a 1RM (xRM) y la velocidad concéntrica media (VCM), optimizando el control de la intensidad del entrenamiento. El objetivo de este estudio fue evaluar la validez del uso de la escala de esfuerzo subjetiva RPE-RIR como herramienta de autorregulación con respecto a los métodos de cuantificación de la intensidad de la carga de entrenamiento. Realizamos una búsqueda sistemática en las bases de datos PubMed, WOS y Scopus. Se revisaron un total de 2.271 artículos, de los cuales 7 cumplieron con los criterios de elegibilidad. En estos estudios participaron 147 sujetos entrenados en fuerza (novatos, experimentados, profesionales, levantadores de pesas), que respondieron a la implementación de protocolos que cuantifican la intensidad de carga subjetiva y objetiva (relación RPE-RIR e intensidad de carga objetiva, velocidad concéntrica media - 1RM/xRM). Se encontraron fuertes correlaciones entre las variables del estudio RPE-RIR/ Velocidad concéntrica media (r = 0,90 - 0,92; r = -0,98 a -1,00; EL: r = 0,85/ r = -0,88, NL: r = 0,85/ r = -0,77), RPE-RIR/1RM (r = 0,88 a 0,91). Las principales conclusiones de esta revisión sistemática en relación con los métodos y medios para cuantificar la intensidad objetiva y subjetiva de la carga de entrenamiento indican una fuerte correlación entre el RPE-RIR (como método subjetivo) y el VCM y 1RM/xRM (como método objetivo), especialmente en poblaciones inexpertas. Sin embargo, estas conclusiones deben considerarse individualmente, dadas las diferencias entre protocolos y movimientos analizados y el análisis limitado de poblaciones noveles.
Palabras clave: Esfuerzo subjetivo, carga de entrenamiento, metodologías de ejercicio

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Introduction

The development of muscle strength and its manifestations is fundamental in training programs focused on sport and health (Naclerio et al., 2011). Here, the incorporation of strength not only results in improved sports performance and musculoskeletal health through neurological and morphological adaptations (Folland & Williams, 2007; Bird, Tarpenning & Marino, 2005). It is important to monitor and regulate the expected stress in training according to individual adaptation, and since recovery, if a stressor is beyond the ability to adapt, the expected improvements may cease or even recede (Helms et al., 2020). The relative intensity, either of a maximum repetition (1RM) or 10/25 RM, can be a determining factor in the adaptations required (Fry, 2004), so the intensity is crucial to maximizing gains in strength training or sports performance (Naclerio et al., Helms et al., 2020; Benedict, 1997; Slimani, Paravlic & Granacher, 2018).

As for the methods of quantifying the load in force training, there are absolute tools such as the 1RM measurement, which represents the maximum load displaced in an attempt to estimate the maximum force (Benedict,1999), being the maximum voluntary expression of strength towards an objective movement, and in turn, objective to the performance of an uprising. However, this maximum expression of force can lead to errors in the application of the test and poor quantification of the evaluation load (Zourdos et al., 2016), in addition when a load is assigned, the 1RM test must be accurate, in contrast to obtaining a true MR, due to many factors that can affect it, such as errors in the administration of the test, as well as an abnormal performance in the lifting (Fleck & Kraemer, 2004), on the other hand, is associated with an increased risk of injury in novice athletes. In turn, the 1RM can improve quickly, so it is inappropriate to plan based on an xRM (González & Sánchez, 2010). In the experience of novice or expert lifters, when quantifying these differences in load or intensity, they do not have the same ability to execute a real 1RM (Zourdos et al., 2016), both from technical aspects and performance.

On the other hand, MRI is not the only way to quantify and monitor the intensity of the training load and thus control the objective aspects of a session. When we consider the execution speed (relative to the executed load), we can see the actual performance of each repetition (González & Sánchez, 2010) and proximity to muscle failure, quantifying more objectively the level of effort (Morán-Navarro et al., 2019), given the high ratio between 1RM and LCA (González & Sánchez, 2010; González-Badilo & Sánchez-Medina, 2010; Pallarés et al., 2014) and muscle failure (Morán-Navarro et al., 2019), in addition, the evaluation of submaximal loads, is more than sufficient to observe changes in performance (Balsalobre & Jiménez, 2014), on the other hand, limitations during prescribed work towards a given percentage of the MRI base the assumption that two subjects working at the same percentage will work at the same intensity or relative effort (Fisher, Steele & Smith, 2013), thus, there can be large variations of repetitions under a given percentage (both in men and women) (González & Sánchez, 2010; Sánchez et al., 2014). This is why the evaluation or control of intensity is presented as a useful tool, which could be used in strength sports, such as powerlifting, in which residual fatigue can affect the programming given the proximity with the 1RM due to the high degree of effort required. Thus, speed-based training reduces the scope for planning errors and maximizes sports performance over a wide range of speeds (Guerriero, Varalda & Piacentini, 2018).

Based on the objective spectra of measurement of the intensity of the force training load, it comprises only one of the monitoring parts, responding to the basis that individuals adapt differently to the same stimuli delivered (Borresen & Lambert, 2009). The other axis includes the quantification of subjective or perceptive aspects of physical effort to the intensity of this load; this perception of physical effort is defined as the subjective intensity of effort, tension, discomfort, and fatigue felt during exercise (Robertson et al., 2003), which allows us to modulate the prescription of training from self-regulation, especially in that training that seeks to maximize strength gains, starting from the assumption of fluctuations in the daily performance of each athlete (Helms et al., 2017; Larsen, Kristiansen, & van den Tillaar, 2021). The first attempt to quantify these subjective factors meant the creation of the first subjective effort measurement scale in 1970, such as Borg's perceived effort rating scale (RPE). This scale was initially based on 21 points per category and was eventually modified to the "Borg 15-point RPE" scale (Borg, 1970; Borg, 1973), this RPE scale being a valid instrument for monitoring perceptive responses and determining effort during the exercise (Hampson et al., 2001). After this, the "CR-10" scale was the first approach to a scale of 10 categories (Borg, 1982), being considered somewhat more appropriate for the measurement of intensity in strength training protocols (Suminski et al., 1997), on the other hand, the "Session-RPE" scale based on "CR-10", allows measuring the perceived subjective intensity after a training session (Sweet et al., 2004; Day et al., 2004). Years later, the "OMNI-RES" scale preceded it, a pictographic scale that measured and sought to investigate values related to the muscles worked and the perception of general effort (Robertson et al., 2003). Under the prediction provided by the RPE scale, higher RPE values are directly associated with increased exercise intensity (Larsen & Kristiansen, 2021; Hampson et al., 2001). In addition to increasing other values related to electromyographic activity in the muscles (Lagally et al.,2004; Lagally et al., 2002; Pincivero et al., 1999) and the progressive accumulation of lactate in the blood (Robertson et al., 2003; Suminski et al., 1997; Lagally et al., 2002; Pierce, Rozenek, & Stone, 1993).

As mentioned above, the OMMNI-RES and CR-10 scales have certain limitations when it comes to reporting the RPE since, despite reaching the fault beyond the will, the RPE values did not coincide with a maximum effort, being lower with respect to this (Hackett et al., 2012; Pritchett et al., 2009). From this basis, it could be assumed in strength training that examining repetitions in reserve (RIR) or near the fault is a more appropriate substitute (currently known as RPE-RIR) compared to the traditional method of absolute scales of RPE (Zourdos et al., 2016) in which the general perception of effort is evaluated, as well as, the RPE based on RIR, while the executed series is closer to the limit or muscle failure (Helms et al., 2016), this associated proximity, is the key of this scale, due to its proximity to an absolute limit (RPE 8-9-10), which in values from 1RPE to 10RPE and undervalues from 7.5RPE to 9.5RPE, measures the missing repetitions to reach the fault (e.g., 8RPE: 2 repetitions remaining or 10RPE maximum effort), the highest values corresponding to the last or last repetitions executed. In addition, this RIR-based scale could facilitate daily self-regulation processes in terms of intensity (Helms et al., 2017a) by adjusting perceptions towards daily fluctuations in performance, given its high correlation with the objective means, RPE-RIR/ Average concentric velocity (Zourdos et al., 2019, Helms et al., 2017a; Odgers et al., 2021; Ormsbee et al., 2019) ($r = 0,90 - 0,92$; $r = -0,98$ to $-1,00$; EL: $r = 0.85/ r = -0.88$, NL: $r = 0.85/ r = -0.77$), RPE-RIR/1RM ($r = 0.88$ to 0.91), in addition to the same RPE-RIR prediction, as prescribed and performed in each session (Helms et al., 2017b; Odgers et al., 2021) values that provide high reliability when prescribing basing subjective and objective methods for a good result.

The facilities granted, thanks to the monitoring of subjective factors with respect to objective factors, can be a great tool to monitor and even quantify the intensity of the expected load in the absence of measurement of both the speed of execution, being also strongly related to movement speed during strength training (Helms et al., 2018; Balsalobre et al., 2018). However, given the dispersion of speed or performance among athletes (especially experienced athletes), it is necessary to create speed or strength profiles that fit the needs of each athlete. (Helms et al., 2017a) , mainly because of these variables, the RIR scale should not be considered alone but in conjunction with other methods or strategies to quantify or prescribe the intensity of the training load (Helms et al., 2016). This review aims to determine the differences between using a subjective effort scale RPE-RIR as a means of self-regulation versus objective methods of quantifying the intensity of the training load.

Methodology

Databases and search strategies

The following systematic review followed the Preferred Reporting Elements guidelines for systematic reviews and meta-analyses (PRISMA) (Page et al., 2021). Scientific articles were searched in PubMed, Web of Science (WoS), and Scopus. The bibliography was compiled in May 2021, in which the search limit considered articles between 2000 and 2021. In addition, the search is limited to articles in English, Spanish, and Portuguese and searches in the fields "Title," "Abstract," and "Keywords."

The first phase of this review was to apply the search strategies used in the three databases consulted. Keywords were combined with the Boolean operator "OR" when they formed two or more terms in word groups classified as Population, Outcome, and Intervention (e.g., "Strength Athletes" or "Resistance Trained Men"), then the search "Y" was used to group the three classifications (for example, "Population or #1" and "Result or #2").

Table 1.
Search strategy PubMed, Web of Science (WoS), and Scopus

ID	PUBMED 2000-2021		
	POPULATION		
1	ALL FIELDS ("strength athletes performance" OR "resistance athletes performance" OR "strength Athletes" OR "resistance athletes" OR "strength-trained men" OR "resistance-trained men" OR "well-trained strength athletes" OR "well-trained resistance athletes" OR "powerlifting athletes" OR "weightlifting athletes" OR "bodybuilding athletes" OR "powerlifters" OR "weightlifters" OR "bodybuilders")	AND	27125
	OUTCOME		
2	ALL FIELDS ("rate of perceived exertion" OR "subjective perception of effort" OR "subjective effort" OR" effort" OR "maximum Effort" OR "relative, subjective effort" OR "relative effort" OR "effort measurement" OR "effort character" OR "exertion" OR "perceived exertion")	AND	211349
	INTERVENTION		
3	ALL FIELDS ("competitive performance" OR "competitive movement performance" OR "compound movement performance" OR "movement velocity" OR "high load performance" OR "maximum strength manifestation" OR "Olympic performance" OR "powerlifting movements" OR "maximal muscular strength" OR "maximal muscular performance" OR "Exercise" OR "Training" OR "Training Session")	AND	904513
4	#1 AND #2 AND #3		2011
	WEB OF SCIENCE		
	POPULATION		
5	TS= ("strength athletes performance" OR "resistance athletes performance" OR "strength Athletes" OR "resistance athletes" OR "strength-trained men" OR "resistance-trained men" OR "well-trained strength athletes" OR "well-trained resistance athletes" OR "powerlifting athletes" OR "weightlifting athletes" OR "bodybuilding athletes" OR "powerlifters" OR "weightlifters" OR "bodybuilders")	AND	1894
	OUTCOME		
6	TS= ("rate of perceived exertion" OR "subjective perception of effort" OR "subjective effort" OR "effort" OR "maximum Effort" OR "relative subjective effort" OR "relative effort" OR "effort measurement" OR "effort character" OR "exertion" OR "perceived exertion")	AND	237750
	INTERVENTION		
7	TS= ("competitive performance" OR "competitive movement performance" OR "compound movement performance" OR "movement velocity" OR "high load performance" OR "maximum strength manifestation" OR "Olympic performance" OR "powerlifting movements" OR "maximal muscular strength" OR "maximal muscular performance" OR "Exercise" OR "Training" OR "Training Session")	AND	811864
8	#5 AND #6 AND #7		112
	SCOPUS		
	POPULATION		
9	TITLE-ABS-KEY ("strength athletes performance" OR "resistance athletes performance" OR "strength Athletes" OR "resistance athletes" OR "strength-trained men" OR "resistance-trained men" OR "well-trained strength athletes" OR "well-trained resistance athletes" OR "powerlifting athletes" OR "weightlifting athletes" OR "bodybuilding athletes" OR "powerlifters" OR "weightlifters" OR "bodybuilders")	AND	2175
	OUTCOME		
10	TITLE-ABS-KEY ("rate of perceived exertion" OR "subjective perception of effort" OR "subjective effort" OR "effort" OR "maximum Effort" OR "relative subjective effort" OR "relative effort" OR "effort measurement" OR "effort character" OR "exertion" OR "perceived exertion")	AND	976358
	INTERVENTION		
11	TITLE-ABS-KEY ("competitive performance" OR "competitive movement performance" OR "compound movement performance" OR "movement velocity" OR "high load performance" OR "maximum strength manifestation" OR "Olympic performance" OR "powerlifting movements" OR "maximal muscular strength" OR "maximal muscular performance" OR "Exercise" OR "Training" OR "Training Session")	AND	1385055
12	#9 AND #10 AND #11		148

The screening of articles and/or the first phase was carried out on the online platform Covidence, which facilitated the process of articles for this review and the corresponding elimination of duplicate articles. The second phase consisted of the selection of articles according to titles and summaries; continuing with the Third Phase, the articles were read in their entirety, eliminating those that did not meet the inclusion and exclusion criteria, using mainly the causes corresponding to "Incorrect intervention," "Elderly population," "Child population," "Incorrect Result" and "Incorrect Comparator," Finally, the fourth phase was performed, reading and in-depth analysis of all those articles that met the inclusion criteria

Eligibility criteria

The strategy provided by the PICOS tool (Methley et al., 2014) was used to determine and organize the inclusion and exclusion criteria of this review, which are determined by the following links: Population (P), Intervention/Exposure (I), Comparator/Control (C), Result (O), Studio design (S)

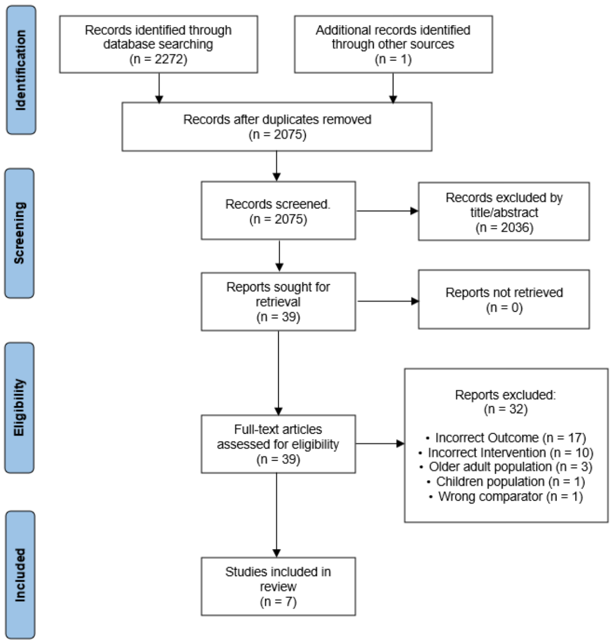

Figure 1. Flowchart of the systematic review process (PRISMA)

Table 2.
Inclusion and exclusion criteria (PICOS)

		INCLUSION CRITERIA
P	Population	Athletes or subjects, men, women, men: women. • Athletes or individuals who practice Powerlifting, Weightlifting, Bodybuilding. • Athletes or subjects trained in strength, advanced, recreational, intermediate, or novice.
I	Intervention/Exposure	• Evaluation of performance in competition movements, such as Squat (SQP, Bench Press (BPP), Deadlift (DLP), Snatch (SN), Clean and Jerk (CY). • Evaluation of performance in movements with general or basic characteristics such as Squat (SQ), Front Squat (FSQ), Smith Squat (STH), Bench Press (BP), Deadlift (DL), Hex bar or trapbar deadlift (HDL), Hip thrust (HT), Pull-ups (PU).
C	Comparator/Control	• Absolute measurement control through objective methods to quantify the intensity of the load, such as 1RM, XRM Find a linear transducer (speed measurement). • Control of subjective methods to quantify the intensity of the load: RPE-RIR
Or	Outcome/Results	• Positive and negative results (RPE-RIR:1RM/xRM o RPE-RIR: average speed o RPE-RIR:1RM:average speed)
S	Study Design	• Comparative, Clinical trials, Observational studies.
		EXCLUSION CRITERIA
	Population	• Athletes or subjects whose main training is not strength training (Runners, Cyclists, Swimmers, etc.) • Athletes and subjects in sports reinstatement. • Athletes and individuals who practice team sports. • Athletes and corresponding subjects of the elderly (≥60 years) and children (≤13 years)
	Intervention/Exposure	• Evaluation of effects on performance, using supplements and equipment that can produce ergogenic effects on performance.
	Comparator/Control.	• Control of subjective methods to quantify the intensity of the load: - CR-10 or CR-100 - S-RPE -Borg 15S - OMNI-RES or RPE-O / RPE-AM

Evaluation of methodological quality

The Physiotherapy Evidence Database or PEDro scale (Morton, 2009) was used to determine the methodological quality of the studies. The 7 selected studies were evaluated based on the 11 criteria of this scale (Pincivero et al., 1999), whose weighted classification is considered low (>4 points), moderate (4 to 7 points), and high (8 to 10 points) (Cashin y McAuley, 2020). The first criterion is not added to the final score. In terms of the PEDro scale: Y: Yes; N: No; 1 (eligibility criteria specified); 2 (subjects were randomly allocated to groups); 3 (allocation concealment was ensured); 4 (groups were similar at baseline regarding the most important prognostic indicators); 5 (all subjects were blinded); 6 (all therapists who administered the therapy were blinded); 7 (all assessors who measured at least one key outcome were blinded); 8 (outcome measures for at least one key outcome were obtained from more than 85% of the subjects initially assigned to groups); 9 (all subjects receiving treatment or assigned to the control group were accounted for in the reported results, or, when this was not possible, data for at least one key outcome was analyzed by "intention to treat"); 10 (results of between-group statistical comparisons for at least one key outcome were reported); 11 (the study provides point measures and measures of variability for at least one key outcome). All studies (7) received a rating of 5 (moderate).

Data extraction

Table 3.
Physiotherapy Evidence Database Scale (PEDro), Evaluation of methodological quality

Articles	PEDro Quality Criteria											
	Selection				Comparability			Results				Score
	1	2	3	4	5	6	7	8	9	10	11	
Helms et al., 2017a	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5
Helms et al., 2018	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5
Helms et al., 2017b	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5
Odgers et al., 2021	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5
Ormsbee et al., 2019	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5
Zourdos et al., 2016	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5
Zourdos et al., 2019	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5

Data extraction regarding the validation of methodologies used in subjective and objective quantification protocols of the intensity of the training load is presented in Table 3. The selection process of this study was carried out by two independent reviewers (S-VM and G-NO) to broaden the possibilities and eligibility criteria according to previously established parameters; in this way, it is possible to develop discussions and/or consensus on the validity of the analysis. This was organized according to the following relevant criteria: (1) author, year, and/or references of the studies (2) population (number of participants, age range, gender distribution (male/female), and experience or type of practical sports (3), research objectives (4), measurement parameter for the variables to be studied (5), types of movements used (6), presentation of the main findings on the criteria measured.

Results

The curret state of knowledge

The search in PubMed databases, Web of Science, and Scopus allowed for obtaining 2011, 112, and 148 articles, respectively, in addition to 1 article collected by manual search. Out of 2,272 articles, 197 duplicates were removed, leaving 2,075 articles. The first bibliographic screening by title and abstract allowed for excluding a total of 2,036 articles from the sample. Of the 39 articles selected as potentially relevant, 32 were discarded during full-text reading. Therefore, only 7 articles were ultimately included for final data extraction after this exclusion process, which followed the PRISMA criteria, and their sequence can be seen in the flow diagram (Figure 1).

Characteristics of subjects and studies

Of the 7 currently included studies (Table 4), the sample sizes ranged from 12 to 29 subjects. The total sample was 147 subjects, of which 5 studies included men/women, and only 2 covered male-only populations. This male population corresponds to 119 participants (81% of the sample), while the female population corresponds to 28 participants (19%). The subjects in the included studies ranged from 20 to 37 years (mean ± SE: age = 28.4 ± 8.4 years). On the other hand, regarding the type of movements analyzed, all studies corresponded to the evaluation of movements with free weights and self-guided movements, whether these movements are related to powerlifting standards, SQP, DLP, and BPP, as well as general strength training movements, such as SQ, BP, HT, FSQ, HDL. Regarding the population's experience in these practices, it corresponds to 33.1% Strength/Endurance Trained Athletes (n=52), 24.8% to Powerlifters and Experienced Powerlifters (n=39), 17.5% to Novice Lifters (n=27), and 18.5% to Experienced Lifters (N=29).

Variables results

Table 4.
Summary of the RPE-RIR methodologies used subjective/objective training intensity quantification protocols (N = 7)

Authors	Subjects	Objectives	Parameters	Movement Type	Results
Helms, Brown, et al. (2017)	12 EPL - 9 (♂) and 3 (♀); Experience: ≥1 year.	Evaluate the ability to select loads using the RPE-RIR classification scale for a single series of SQP-DLP-BPP in hT, pT, and sT sessions for 3 weeks	Self-loading/RPE target based on RPE-RIR. RPE-diff based on RPE-RIR	Self-guided movements*: SQP-BPP-DLP	SQP RPE-diff: hT (-0.19 ± 0.21 RPE); pT (-0.10 0.45 RPE); sT (0.01 ± 0.37 RPE) BPP RPE-diff: hT (0.14 ± 0.44 RPE); pT (-0.21 0.35 RPE); sT (0.15 ± 0.42 RPE) DLP RPE-diff: pT (-0.08 ± 0.23 RPE); sT (0.04 ± 0.41 RPE) No significant RPE target differences in DLP-SQP-BPP in pT and sT. 8 repetitions/ RPE (8) may have better BPP accuracy than SQP. Improved BPP accuracy closer to failure.
Helms et al. (2018)	12 EPL - 9 (♂) and 3 (♀); Experience: ≥1 year	To observe the impact of the implementation of RPE stops in the training volume in EPL that perform SQP-DLP-BPP in 3 weekly sessions: 1 hT, 1 sT, and 1 pT for 3 weeks.	RPE Stop based on RPE-RIR as a Method of self-regulation of training volume.	Self-guided movements *: SQP-BPP-DLP	It appears that volume self-regulation using RPE Stop effectively dictates the sets to perform. Volume at BPP is significantly higher (hT-pT-sT), based on reductions of 2% > 4% > 6% (RPE stop) Volume at SQP is higher by 6% vs 2% Volume in DLP was higher at 6% vs 2 and 4%.
Helms, Storey,	15 PLA - 12 (♂)	Assess both RPE-RIR and average	RPE-RIR and	Self-guided	In SQP-BPP-DLP:

et al. (2017)	and 3 (♀); Experience: ≥1 year.	speed in male and female EPL, in SQP-DLP-BPP, in order of competition and determine any relationship between RPE and average speed.	ACV were recorded in lifting ≥80% of 1RM.	movements *: SQP-BPP-DLP	Strong relationship between %1RM and RPE-RIR (r = 0.88 to 0.91) Strong relationship between PCV and %1RM (r = 0.79 to 0.87) A very strong relationship between ACV and RPE-RIR (r = 0.90 to 0.92)
Odgers et al. (2021)	27 ST - 14 (♂) and 13 (♀) – Experience: 1 year.	To examine the accuracy of intra-set RPE-RIR and establish RPE/speed ratios in FSQ and HDL, in ST men and women.	RPE predicted versus RPE-RIR, expressed in RPE-diff (or RPE difference) in RPE9 and RPE6	Self-guided movements *: FSQ-HDL	FSQ-HDL: Significant inverse relationships between ACV and RPE-RIR (r = -0.98 – a -1.00) HDL: ♂ RPE-diff RPE9 (0.25 ± 0.46) vs RPE6 (1.00 ± 1.12) ♀ RPE-diff RPE9 (0.21 ± 0.44) vs RPE6 (1.19 ± 1.16) FSQ: ♂RPE-diff significantly lower RPE9 (0.09 ± 0.19) vs RPE6 (0.71 ± 0.70) ♀ RPE-diff RPE9 (0.19 ± 0.36) vs RPE6 (0.86 ± 0.88)
Ormsbee et al., (2019)	PA: 14 EL y 13 NL - 27 (♂); Experience: EL >2 years y NL ≥3 months.	To examine the application of the RPE-RIR scale and the corresponding PCVs during a BP 1RM test and in single repetition sets of 60, 75, and 90% 1RM, and one set of 8 repetitions at 70% 1RM in EL and NL.	RPE-RIR was recorded at 60, 75, and 90% of 1RM and series of 70% 1RM. ACV in 1RM attempts; 1st and 8th repetition 70% 1RM.	Self-guided movements *: BP	RPE-RIR in BP of EL reports higher values (9.86 ± 0.14) than NL (9.35 ± 0.36). No differences between EL and NL regarding ACV and RPE at other intensities. Strong significant inverse relationships for both EL (r = 0.85) and NL (r = 0.85) between ACV and RPE at all intensities.
Zourdos et al., (2016)	15 EL - 12 (♂) and 3 (♀); 14 NL - 11 (♂) and 3 (♀); Experience: EL >2 years y NL >1 year.	Compare the RPE-RIR ratings, where an RPE 10 equals 0 RIR, an RPE 9 equals 1 RIR, and so on at 100%, 60%, 70%, 75%, and 90% 1RM EL and NL during the SQ exercise.	RPE-RIR after each 1RM attempts RPE-RIR in sets of 60, 70, 75, 90%1RM.	Self-guided movements *: SQ	EL: Strong inverse relationships in RPE-RIR to ACV in all %1RM (r = -0.88) NL= Strong inverse relationships in RPE-RIR to ACV in all %1RM (r = -0.77)
Zourdos et al., (2019)	25 ST (♂); Experience: 1SQ/weeks by ≥2 years.	Examine the accuracy of measuring intra-set RPE-RIR when verbally called by the lifter with a perceived RPE of "5", "7", and "9" (5, 3, and 1 RIR) before continuing the set to a set. Voluntary sT failure.	RPE-RIR assignment in each 1RM attempt. Intra-set RPE-RIR a assignment to putative "5RPE-5RIR", "7RPE-3RIR" and "9RPE-1RIR" in 70%1RM series. RIR-diff or Difference of predicted RIR and actual RIR during 5RPE, 7RPE, and 9RPE	Self-guided movements *: SQ	Lowest RIR-diff close to failure. RPE-diff: 9RPE= 2.05 ± 1.73 repetitions 7RPE= 3.65 ± 2.46 repetitions 5RPE=5.15 ± 2.92 repetitions

Training Type/Movement Type/Training Variables": sT: Strength training; pT: Power training; hT: hypertrophy training; RPE-diff: difference RPE predicted and executed; RIR-diff: difference RIR predicted and executed; SG: Self-Guided Movements (Squat/Bench Press/Deadlift/Pull-ups); MG: Machine Guided Movements (Squat Smith/Press Smith/Deadlift Smith); ACV: Average Concentric Velocity; "Movement, suffix (P) powerlifting": SQP: Squat; BPP: Bank Pressure; DLP: Dead Weight; SQ: Squat; FSQ: Front Squat; STH: Smith squat; BP: Bench Press; DL: Deadlift; HDL: hexagonal bar deadlift; HT: Hip thrust PU: Dominated; "Population": ♂: Male; ♀: Female; ST: Athletes or subjects trained in strength; EPL: Experienced Powerlifters; EL: Experienced lifters NL: Novice lifters; RL: Recreational lifters PLA: Powerlifting athletes; PA: Physically active subjects; NPA: Subjects not physically active

Table 4 presents the main results regarding the methodologies that involve RPE-RIR as a subjective scale for self-regulation compared to objective scales for training load intensity. Helms et al. (2017) introduced the RPE-RIR scale as a method for selecting loads for single-set sessions in hypertrophy, power, and strength training for volume regulation, in which no significant differences were observed for objective RPE in DLP, SQP, and BPP in power and strength training sessions, highlighting the accuracy of RPE near failure in BPP. Helms et al. (2018) complemented RPE-RIR with the RPE-STOP methodology for volume self-regulation, showing that it appears to be effective in dictating sets to be performed, although volume in both SQP and DLP was greater with an RPE-STOP of 6% than with the 2 %.

The RPE-RIR scale also presents a relationship with objective parameters that respond to the intensity of the load, such as %1RM or xRM and average concentric velocity (ACV). Regarding ACV and RPE-RIR, Helms et al. (2020) show a strong relationship between these variables ACV/RPE for SQP, BPP, and DLP (r = 0.90 to 0.92);

Ormsbee et al. (2019) indicate significant strong inverse relationships for BP, PCV/RPE (r = 0.85) for EL and PCV/RPE (r = 0.85) for NL at all intensities, and EL presents higher raw RPE-RIR values (9.86 ± 0.14) to NL (9.35 ± 0.36); for Zourdos et al. (8), EL presents strong inverse relationships PCV/RPE (r = -0.88) and for NL strong inverse relationships PCV/RPE (r = -0.77) in SQ, for every %1RM. At the same time, Helms et al. (2020) present a strong relationship between %1RM/RPE-RIR (r = 0.88 to 0.91) as well as a strong relationship between %1RM/ACV (r = 0.79 to 0.87).

On the other hand, there are two similar differentiation scales based on RPE and RIR between what is predicted and what is executed: RPE-diff by Odgers et al. (Odgers et al., 2021) and RIR-diff by Zourdos et al. (2021). Odgers et al. (2021) present RPE-RIR prediction as RPE-diff in sets located at RPE6 and RPE9, in which ACV and RPE-RIR have a significant inverse relationship (r = -0.98 to -1.00). In addition, both in HDL and FSQ (men and women), the RPE-diff at RPE9 (HDL♂: 0.25 ± 0.46; HDL♀: 0.21 ± 0.44; FSQ♂: 0.09 ± 0.19; FSQ♀: 0.19 ± 0.36) was lower compared to RPE6 (HDL♂: 1.00 ± 1.12; HDL♀: 1.19 ± 1.16; FSQ♂: 0.71 ± 0.70; FSQ♀: 0.86 ± 0.88).

Zourdos et al. (2021) present this prediction as RIR-diff, the difference between the planned RIR and the executed RIR for RPE in RPE5, RPE7, and RPE9 sets at 70%1RM. This RIR-diff is less close to failure, with differences in repetitions between RPE of 2.05 ± 1.73 repetitions for an RPE9, 3.65 ± 2.46 repetitions for an RPE7 and 5.15 ± 2.92 repetitions for an RPE5.

On the other hand, Helms et al. (2017b) distributed RPE-diff in different daily training goals for hypertrophy training and power-training for strength, respectively. In terms of SQP, the distribution of RPE-diff was not significantly different (p=0.07 to 0.76) compared to hypertrophy training (-0.19 ± 0.21 RPE), power training (-0.10 ± 0.45 RPE), and strength training (0.01 ± 0.37 RPE). On the other hand, in BPP, the distribution of RPE-diff between hypertrophy training (0.14 ± 0.44 RPE) and strength training (0.15 ± 0.42 RPE) was not significantly different (p = 0.94). During strength training, the executed RPE was significantly closer (p = 0.02) to the target RPE compared to power training (-0.21 ± 0.35 RPE). As for RPE-diff in DLP during power training (-0.08 ± 0.23 RPE) and strength training (0.04 ± 0.41 RPE), it was not significantly different (p = 0.16).

Discussion

This systematic review presents the main findings regarding the means and methods for quantifying the intensity of load, both subjectively (RPE scale based on RIR) and objectively (based on %RM and ACV), and their relationship to each other, which respond to strength training and its manifestations in trained strength populations. The main findings of this study point to a strong correlation between RPE/RIR and ACV, in addition to the classic intensity quantification related to 1RM or xRM and RPE-RIR. On the other hand, the evidence supports that the higher the EPR assignment, the greater the accuracy in predicting RPE and RIR in sets assigned to an intensity between RPE5 and RPE9. Furthermore, the RPE-Target or RPE objective methodology based on RPE-RIR, as a means of self-regulating the training volume in hypertrophy, power, and strength training sessions, highlights the precision of RPE near failure, at least in BPP, without showing significant differences in RPE in DLP, BPP, and SQP. Additionally, the RPE-STOP methodology based on RPE-RIR seems effective in dictating sets in strength training for volume self-regulation. However, despite these main findings, it is fundamental to expose the relevance of these ways of quantifying the intensity of load (objective and subjective) from the singularity of each, given the different protocols addressed in this review.

Regarding the various forms and/or methodologies underlying the RPE-RIR scale, under a single objective for each training protocol, such as an RPE objective versus objective variables such as ACV and %xRM, which allow for the regulation and/or self-regulation of the variables that affect the subjective and objective aspects of training intensity, there is a relationship between the proposed predictions in each training (regarding RPE-RIR) which are indicated as RPE-diff (Helms et al., 2017b; Odgers et al., 2021) or RIR-diff (Zourdos et al. 2021), which mostly show the difference between an objective RPE and the RPE executed in training. Although the protocols and movements to be performed differ, the authors agree on certain aspects. On the one hand, Helms et al. (Helms et al. 2017b) did not show significant differences for objective RPE compared to RPE-diff in DLP-SQP-BPP in both power and strength training (RPE 8 and 9 respectively, RIR 2 or 1 near failure); therefore, the higher the RPE and the lower the RIR, the greater the scale's precision. Regarding Odgers et al. (2021) and their analysis in HDL and FSQ, RPE-diff was significantly lower for RPE9 (RIR 1) versus RPE6 (RIR 4) for both men and women, highlighting again the intra-set RIR predictions and their accuracy near failure, although they consider that although RPE can measure proximity to failure, the rating is "subjective." At the same time, Zourdos et al. (2021) mention that RIR-diff with respect to SQ is less close to failure, so the greater the number of executed repetitions, the lower the precision in RIR (RPE5 and RPE7), suggesting that ≥3 far from failure, greater difficulty in predicting RIR. Regarding this, the authors consider muscle failure for its precision necessary to correctly determine RIR to increase the objectivity of what was executed compared to subjective perception.

On the one hand, this first approach to RPE accuracy expressed as RPE-diff and RIR-diff directly correlate with the mentioned variables (ACV-1RM-xRM); hence, most articles report this positive correlation. However, Helms et al. (2017b), in SQP-BPP-DLP, observed very strong relationships between %1RM and RPE, as well as strong inverse relationships between RPE and ACV; during the 1RM, the RPE reached "almost maximum" scores. Odgers et al. (2021), on the other hand, in FSQ-HDL, found almost perfect inverse relationships (r = -0.97 -1.00) between RPE and ACV for both men and women, as well as no differences between sexes for ACV and 1RM values. However, these findings should be taken cautiously, as most articles, despite indicating a mixed population (mostly male), do not report preliminary or exclusive results for the female population. Zourdos et al. (2021), in the SQ, mention that well-trained men measured this RPE during sets more accurately in sets close to failure at 70% of 1RM. However, part of their limitations lies in the blinding method towards the load and the previous 1RM test before the protocol to failure determined at this 70%. More recently, Odgers et al. (2021) mentioned that the ACV relationship with respect to 1RM failure may be specific to each exercise. Additionally, the RPE/PCV relationship presented does not extrapolate to other exercises (Odgers et al., 2021; Zourdos et al., 2021). Furthermore, the relationships of the objective mean (1RM-ACV) must be developed under an individually tailored "load-velocity profile" (Helms et al., 2017b).

On the other hand, the authors like to compare the RPE-RIR interaction in ACV and 1RM/xRM in EL and NL populations with Ormsbee et al. (Ormsbee et al., 2019) and Zourdos et al. (Zourdos et al. 2016) in BP. Ormsbee et al. (2019) based their protocol on BP and different %1RM, in which both EL and NL obtained a strong inverse correlation between RPE/ACV at all %1RM. However, 71.43% of EL and 23.08% of NL registered a value of RPE10 during 1RM. Zourdos et al. (2016) also showed a strong inverse relationship between RPE/ACV in EL and NL. Similar findings regarding maximum effort showed that 66.7% of EL and 14.29% of NL registered an RPE10 during 1RM, with 100% of EL perceiving an RPE ≥9 during 1RM, while 35.71% of NL perceived an RPE lower than 9. Additionally, EL in Ormsbee et al. (Ormsbee et al., 2019) recorded higher RPEs at "100%" of 1RM, coinciding with slower speeds, suggesting closer proximity to the true 1RM, as Zourdos et al. (2016) found that EL with respect to NL performed ACV slower near 1RM; thus, EL may not have the same abilities to perform a true 1RM as NL.

Based on the RPE-diff-RIR-diff premise and prediction, Helms et al. (2018) used the RPE-RIR scale, based on RPE-STOP, for adjusting and self-regulating training volume by incorporating 2%, 4%, and 6% stops with the target intensity during hypertrophy, power, and strength training periods, respectively. The training volume appears to increase with higher percentage stops (6%>4%>2%). However, only the total volume relative to BPP (sum of hypertrophy/power/strength training) was significantly different among the three weeks of the protocol. Concerning SQP and DLP volume, there was no significant difference between all weeks. Therefore, it seems plausible to effectively self-regulate volume using this methodology to dictate the number of sets performed. Despite these findings, most articles rely on competitive or experienced powerlifters (González y Sánchez, 2010; Lagally et al., 2004) and strength-trained athletes (Odgers et al., 2021) as their study subjects, which limits the generalizability of their findings. Conversely, studies with mixed experienced populations suggest that the accuracy of RPE is directly related to training experience (Zourdos et al.,2016); Ormsbee et al., 2019). Additionally, chronological age was significantly and inversely related to RIR-diff (RPE9), meaning that a "mature" or "experienced" subject may have a more realistic interpretation of their limitations as they approach failure (Zourdos et al., 2021).

Based on the objectivity of RIR and the correlations found between ACV/%RM and RPE-RIR, some protocols were not executed to failure, so it is unknown whether the reported RPEs represented a true RIR (Helms et al. 2017a). However, it is unnecessary to consider failure to optimize strength and hypertrophy because this situation prolongs recovery, training frequency, and even training volume (Zourdos et al., 2021). In contrast, to optimize strength and hypertrophy training, the methodology based on RPE-STOP can be effective for self-regulating training volume (Helms et al., 2018) because it is based on RPE-RIR and allows for the regulation of both objective and subjective effort to the quantified unit, execution, or repetition, and its respective "feeling," controlling fatigue levels for total a volume in key periods or cycles, such as strength, power, and hypertrophy cycles

Practical applications

The RPE scale is presented as a tool that allows for direct measurement of strength training needs, as is RIR integrated with RPE or RPE-RIR. In the absence of objective measurement instruments of intensity or with difficult access for coaches, RPE is a viable alternative for controlling RIR in well-trained individuals (Zourdos et al., 2021) due to its high correlation with ACV and 1RM or xRM. Helms et al. (Helms et al., 2020) indicated that, under these correlations, its use could improve strength gains, although previously, Helms et al. (2017a) recommended prior experience with RPE during percentage-based training programs before assigning an RPE. It is important to note that working under %1RM may not be appropriate for EL and NL populations, as they may not possess the same abilities to experience maximum effort (Zourdos et al., 2016). Therefore, a supervised familiarization period is suggested to reduce these inter-individual differences in scale interpretation (Naclerio & Larumbe-Zabala, 2017).

Ormsbee et al. (2019) suggest that athletes could be prescribed an objective RPE range and finish the exercise once that range is exceeded, providing a practical alternative in velocity-based training. Perhaps for this reason, Zourdos et al. (2021) recommend that RPE-RIR be used at higher intensities (≥80% of 1RM), as high repetition sets lead to inaccurate RIR predictions. Otherwise, ranges of RPE-RIR, such as "5 to 7" or "6 to 8," are recommended instead of an exact number. Additionally, Ormsbee et al. (2019) indicate that the inclusion of non-integer numbers such as "7.5," "8.5," or "9.5," especially near 1RM, can assist in selecting loading attempts, allowing for greater precision in RPE reports. Under this premise, Pageaux (2016) shows the disadvantage of the classic CR-10 scale, which does not offer sufficient rating possibilities to detect those small changes in effort. On the other hand, Helms et al. (2018) indicate that through RPE-STOP methodologies and their self-regulation system, the volume of training and stress can match the desired focus of a block within a periodized macrocycle.

Study limitations

In this systematic review, certain limitations must be acknowledged, such as the lack of studies involving the RPE-RIR scale, especially highlighting the small number of studies that utilize similar methodologies (given the different ways in which RPE-RIR is used for self-regulation), which complicates the interpretation of results in a population that encompasses heterogeneity (gender, experience, etc.). Regarding this, only one of the present studies explicitly reports results related to the female population, which does not allow for definitive conclusions to be drawn. Furthermore, there is a lack of evidence to support preliminary findings in a novice population. On the other hand, the ergogenic effects of supplementation, implementation, and/or sports apparel on lifting performance have not been integrated, which could impact RPE-RIR during the execution of the specific protocols.

Conclusion

The main findings of this systematic review regarding methods and means to quantify the objective and subjective intensity of training load indicate a strong correlation between RPE-RIR (as a subjective method) and ACV and 1RM/xRM (as an objective method), especially inexperienced populations (EPL-PLA-EL-ST). However, these conclusions should be considered individually, given the differences between protocols and analyzed movements and the limited analysis of novice populations. In any case, a familiarization period with this scale is recommended, and ideally, it should be implemented immediately when objective means of measuring training load intensity are available. Being a subjective tool, it requires a period of adjustment to these demands. However, its advantage is the lack of need for high-cost instruments, making it an accessible tool for all coaches, teachers, physical trainers, and researchers to self-regulate both the intensity and volume of training or training cycles in conjunction with or in contrast to objective means (ACV and 1RM).

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