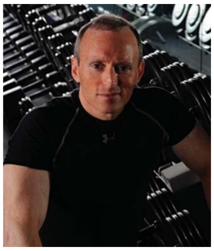

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COLUMN EDITOR: Brad Schoenfeld, PhD, CSCS, CSPS, NSCA-CPT

Application of the Repetitions in Reserve-Based Rating of Perceived Exertion Scale for Resistance Training

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ABSTRACT

RATINGS OF PERCEIVED EXERTION ARE A VALID METHOD OF ESTIMATING THE INTENSITY OF A RESISTANCE TRAINING EXERCISE OR SESSION. SCORES ARE GIVEN AFTER COMPLETION OF AN EXERCISE OR TRAINING SESSION FOR THE PURPOSES OF ATHLETE MONITORING. HOWEVER, A NEWLY DEVELOPED SCALE BASED ON HOW MANY REPETITIONS ARE REMAINING AT THE COMPLETION OF A SET MAY BE A MORE PRECISE TOOL. THIS APPROACH ADJUSTS LOADS AUTOMATICALLY TO MATCH ATHLETE CAPABILITIES ON A SET-TO-SET BASIS AND MAY MORE ACCURATELY GAUGE INTENSITY AT NEAR-LIMIT LOADS. THIS ARTICLE OUTLINES HOW TO INCORPORATE THIS NOVEL SCALE INTO A TRAINING PLAN.

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INTRODUCTION

A rating of perceived exertion (RPE) scale is a tool used to monitor the perceptual response to training, which has been well established as a method of determining exertion during exercise (21). The original RPE scale was developed by Gunnar Borg over 40 years ago (5) and has been primarily used to monitor aerobic exercise. The original scale rated exertion from 6–20 to roughly match heart rate, and therefore its application to resistance training may have been limited. Its creation was followed shortly by the development of Borg's category (C) ratio (R) scale. The Borg CR10 Scale was the first scale to provide exertion ratings from 1 to 10, and it was followed by the creation of a visually aided 1–10 RPE scale known as the OMNI scale (14). However, more recently RPE has been used through these 3 aforementioned scales to gauge effort during resistance training (29). Although there are slight differences in the nomenclature and numerical ranges of these scales, all have been determined valid methods of quantifying perceived exertion (14).

There are different ways to use RPE scores in resistance training. Scores can be obtained from the lifter after each exercise or group of exercises, or alternatively using the session RPE method, whereby 30 minutes after a session is completed an RPE score for the entire training bout is obtained (15). Session RPE can be used to prescribe intensity for an entire training session or to monitor the global response to training over time to make adjustments to a periodization plan (9). However, if a strength and conditioning practitioner wishes to prescribe intensity using RPE on a set-to-set basis, the traditional RPE scale has limitations. Arguably the most important limitation is that less than maximal RPE scores are often reported even when the maximal number of repetitions are performed at a given load (19,33,42).

In fact, Hackett et al. (2012) explored this limitation by measuring both the estimated repetitions remaining, actual repetitions remaining, and the RPE in bodybuilders performing the bench press and squat. To do so, the researchers had the participants perform 5 repeated sets at 70% of one repetition maximum (1RM) for 10 repetitions (or to failure if 10 repetitions could not be completed) with 5 minutes rest between sets. At full extension in both the squat (standing at full extension) and bench press (arms extended with elbows locked), on completion of the 10th repetition of each set, participants verbalized either how many more repetitions they believed they could perform before reaching failure or a 1–10 RPE score (whether remaining repetitions or RPE was reported was randomized). Then, while receiving verbal encouragement from spotters they continued the set to muscular failure to determine actual repetitions remaining.

Hackett et al. discovered that not only did participants report RPE ratings that fell short of maximal (less than 10) even when sets were taken to volitional failure (no further repetitions could be performed), but that the participants had a high degree of accuracy in estimating their number of repetitions remaining on a set. The actual and estimated number of repetitions performed by the lifters were highly related for both the bench press ($r = 0.95$) and squat ($r = 0.93$). In addition, with each subsequent set the participants were able to more accurately gauge the number of repetitions remaining. Meaning, that as fatigue mounted from previous sets and the closer to failure a set was taken, the more accurate the estimation of repetitions remaining became (19). However, a disconnect remained as Hackett et al. (2012) had athletes use two different scales to assess RPE and repetitions remaining, thus it may be more appropriate to present 1 scale to athletes for feasibility and ease of use.

For this reason, Zourdos et al. recently investigated the use of a 1–10 scale inwhich RPE value corresponds to a number of repetitions in reserve (RIR) (i.e., 10 RPE = 1 RIR; 9 RPE = 2 RIR, and so forth) in experienced (those who had >1 year experience performing the barbell back squat) and novice (those who had <1 year experience) squatters (48). Because Hackett et al. (2012) found athletes' estimates of repetitions remaining were more accurate when a set was closer to failure, this scale was developed using RIR descriptors for scores of 5–10 and descriptors of perceived effort to describe scores from 1 to 4. In addition, scores of 5–6 were grouped as 4–6 RIR as it is easier for athletes to give a range of RIR when RIR is greater than 3. Zourdos et al. also found substantial differences between novice and experienced squatters which have important implications for the use of this scale. The scale introduced by Zourdos et al. can be seen in Table 1. It must be noted that although Zourdos et al. have introduced an RIR-based scale into the scientific literature, a scale of this type was originally created in "The Reactive Training Systems Manual" in 2008 to be used in powerlifting-type training (45). Based on these recent studies, it seems that a scale based on RIR has a number of potential applications in resistance training, which this review will examine.

Table 1
Resistance training specific rating of perceived exertion (48)

Rating	Description of perceived exertion
10	Maximum effort
9	1 repetition remaining
8	2 repetitions remaining
7	3 repetitions remaining
5–6	4–6 repetitions remaining
3–4	Light effort
1–2	Little to no effort

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BENEFITS OF USING A REPETITIONS IN RESERVE–BASED SCALE FOR PRESCRIBING INTENSITY

Although it may be a more accurate method of determining near-limit loads for resistance training compared with the traditional RPE scales (19), the RIR-based scale also shares many of the beneficial traits associated with traditional RPE. There is inherent variation in human performance because of normal biological and psychological variability and factors such as sleep (6), nutrition (23), and life stress (4) all may affect strength during training or during testing. In addition, rates of progress and recovery are highly individual (16,44). Methods of determining intensity such as percentage of 1RM and RM are based on a previous performance that may not be representative of an athlete's current status. 1RM is not stable in novice populations (36) and can be suppressed by fatigue from previous training mesocycles (28). Thus, if a 1RM or RM test happens to be reflective of an abnormal performance, positive or negative, subsequent training loads would be lighter or heavier than intended. Likewise, even if a test does accurately reflect current strength, subsequent percentage 1RM loading does not account for day-to-day fluctuations in performance. Also, despite the common use of tables showing "repetitions allowed" at different percentages of 1RM in professional texts (3), there are interindividual variations in how many repetitions can be performed at the same percentage of 1RM (35). To conclude, the RIR-based scale not only shares the benefit of putting all individuals on a "level playing field" that traditional RPE enjoys but also has the unique advantage of being more valid than traditional RPE for sets performed with near-limit loading (19).

If a practitioner decides to use an RIR-based scale to prescribe intensity, care must be taken to ensure it is properly implemented. The ability to accurately gauge traditional RPE is greater in those experienced with resistance training compared with novices (13,43), and this seems to hold true when using an RIR-based scale as well. In a recent study by Zourdos et al., comparing the use of an RIR-based scale in experienced and novice squatters, not only were experienced squatters more often able to provide accurate scores at 1RM (9.80 ± 0.18 versus 8.96 ± 0.43, $p = 0.023$), but the inverse association between scores and velocity was stronger in experienced compared with novice squatters ($r = -0.88$ versus $r = -0.77$) (48). This relationship between RIR and velocity is important; as per the load-velocity relationship, as intensity increases the speed of movement decreases. For example, in competitive powerlifting, a sport where one of the goals of the competitor is to squat as heavy a load as possible for a single repetition, it has been said that an attempted lift that is just barely completed at the slowest speed possible is indicative of the best performance capable by that lifter (17). This is not to say that loads are intentionally moved slow, but rather that experienced lifters due to their extensive neuromuscular adaptations and their ability to hold form at very heavy loads, can "grind" through heavier attempts than novice lifters at slower speeds without failing. For this reason, the ability to complete maximal lifts at very slow speeds can be viewed as a sign of neuromuscular efficiency, with regard to maximal strength, and indicative of an experienced lifter (48). Thus, for this RIR-based scale to be seen as a valid measure of assessing intensity, final-repetition velocity should decrease as the score of a given set increases. Therefore, the stronger inverse relationship observed in experienced squatters seems to indicate that experienced lifters are more accurate in gauging RIR.

Similar to previous data (19), Zourdos et al. also observed that experienced lifters are more consistent at gauging RIR as they approach failure (48). This is indicated by a decrease in the variability of scores as lifters performed single repetitions at increasing intensities. The standard deviation of the scores reported for single repetitions at 100, 90, 75, and 60% of 1RM were 0.32, 0.92, 0.97, and 1.18, respectively, for the experienced squatters (48). The data from Zourdos et al. clearly suggests experienced lifters to record more accurate scores than novice lifters. Therefore, novice lifters should practice recording RIR, but likely not base training intensity or progression solely on the RIR-based scale until increased accuracy is achieved. A possible way to gauge this is to take a submaximal set short of failure and record a score followed by a subsequent set at the same load that is taken to failure to test if the score was accurate. Once accuracy is established, RIR scores should primarily be used for training goals that require sets to be completed near, or a few repetitions short of volitional failure (RPE 7–10). Therefore, the use of the RIR-based scale should primarily be relegated to training goals such as strength, hypertrophy, muscular endurance, or heavy power training.

To conclude, implementation of the RIR-based scale with novice and experienced lifters for various training goals is possible. However, the RIR-based scale should be implemented only as an additional variable to be tracked alongside normal training data with novice lifters. This serves to increase the awareness of how close each set is performed to failure, and to therefore familiarize the user with the scale. Once the lifter has advanced past the novice stage, the use of this scale for intensity prescription can be considered. However, before implementing the scale in this manner, a session dedicated to testing the lifter's rating accuracy with the scale should be performed.

Furthermore, prescribing intensity using an RIR-based scale is not mutually exclusive with prescribing intensity using percentage 1RM or RM values. If a practitioner wishes to use these arguably more objective measures of intensity, they can also use RIR in conjunction with a RM or percentage 1RM prescription to ensure the intended stress matches the experienced stress of the lifter. For example, if a practitioner prescribes 3 sets of 3 repetitions at 90% 1RM, they might expect on a good day for the lifter to be able to complete the initial 2 sets with 1 repetition remaining, and for the final set to be near maximal. To ensure that this intended intensity is what is experienced, they can concurrently prescribe "0–1 RIR on all sets" so that the lifter knows to reduce the intensity if they are unable to complete 3 repetitions, or to increase the intensity if they are able to complete sets with more than 1 RIR. This approach could also be used with an RM prescription if the practitioner wishes for the lifter to stop short of muscular failure. For example, a "5RM with 1 RIR" could be prescribed so that the lifter knows to use the heaviest load they can lift for 5 repetitions, while stopping the set with 1 RIR.

Table 2
Relationship with percentage 1RM, repetitions performed and RIR-based RPE

	Repetitions performed							
RPE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
10	**100**[a]%	95.0%	91.0%	87.0%	85.0%	83.0%	81.0%	79.0%
9.5	97.0%	93.0%	89.0%	86.0%	84.0%	82.0%	80.0%	77.5%
9	95.0%	91.0%	87.0%	85.0%	83.0%	81.0%	79.0%	76.0%
8.5	93.0%	89.0%	86.0%	84.0%	82.0%	80.0%	77.5%	74.5%
8	**91**[a]%	87.0%	85.0%	83.0%	81.0%	79.0%	76.0%	73.0%
7.5	89.0%	86.0%	84.0%	82.0%	80.0%	77.5%	74.5%	71.5%
7	87.0%	85.0%	83.0%	81.0%	79.0%	76.0%	73.0%	**70**[a]%

[a]These bolded values are the mean percentage 1RM values from sets performed in Zourdos et al. (48).

1RM = one repetition maximum; RPE = rating of perceived exertion; RIR = repetitions in reserve.

RELATIONSHIP OF PERCENTAGE ONE REPETITION MAXIMUM, REPETITIONS PERFORMED, AND REPETITIONS IN RESERVE

For practitioners used to prescribing intensity based on percentage 1RM (and RM) and its relationship with repetitions allowed, we direct them to Table 2, which is a conversion chart based on the mean RIR-based RPE scores reported by the experienced squatters for the single repetition sets at 90 and 100% 1RM, and the 8 repetition set at 70% 1RM in the publication by Zourdos et al. (48). This chart is not without limitations as it is based on the mean scores specific to the trained lifters in this study only. Values for percentage 1RM repetition combinations besides single repetitions at 90 and 100% 1RM and 8 repetitions at 70% 1RM are estimations. In addition, as previously stated, there are significant differences in how many repetitions can be performed at the same percentage of 1RM by different individuals (35). Furthermore, this chart is based on the barbell back squat, and this relationship may change with machine-based, single-joint, or upper-body exercises. Finally, this chart is based on the mean scores from Zourdos et al. (48). Statistically, this is important to note due to individual differences in the ability to perform repetitions at different percentages of 1RM. For example, the standard deviation reported at 8 repetitions at 70% of 1RM was 1.2. Meaning, that roughly two-thirds of lifters when performing a set of 8 repetitions at 70% of 1RM may report an RIR between 2 and 4, whereas some lifters may report an RIR as low as 1 or as high as 5. Therefore, this chart should be primarily used to conceptualize the relationship between repetitions performed, percentage of 1RM and RIR scores in trained lifters. It should not be viewed as an absolute conversion tool because of individual differences and day-to-day variations in strength that were discussed earlier in this review.

INCORPORATING THE SCALE INTO PROGRAMMING

Once an athlete is determined to be adequately experienced with resistance training and has been familiarized using the scale, it can be integrated into any training plan designed to maximize hypertrophy, muscular endurance, strength, or power at relatively heavy loads. Because of the inaccuracy of gauging RIR when a set is completed far from volitional failure, it would not be appropriate to use this scale for low to moderate intensity, high-velocity power training (under 80% 1RM) if the goal is to have an accurate gauge of RIR (3). However, the development of power in the high-force portion of the force-velocity curve could be targeted using this scale (20). That said, a potential use for this scale for low to moderate intensity, high-velocity power training may exist by setting an "intensity cap" on sets performed. Because the scale has subjective descriptors of effort for values below 5 (1–2 RPE = "little to no effort," 3–4 RPE = "light effort"), it could be used to determine if high-velocity power training is being performed in an explosive enough manner, by limiting sets to loads that can be performed at an RPE no higher than 4. Thus, this illustrates the additional advantage of a combined RPE/RIR scale rather than solely focusing on one or the other.

As previously mentioned, intensity can be prescribed using percentage 1RM or as an RM with a reference RIR value, or if the lifter is appropriately familiarized with this scale a practitioner can prescribe only a repetition target (or range) and a target RIR (or RIR range). For example, if the practitioner wishes for the lifter to perform 3 sets of 10 repetitions, 1 or 2 repetitions short of failure, they would prescribe: "3 × 10 at RPE 8–9 (i.e., 2 or 1 RIR)." The lifter would then select a load with which they believe they could complete 10 repetitions, 1–2 repetitions short of failure (based on previous training experience, perceived readiness on the day of, and RPE scores on warm-up sets). To further aid practitioners who wish to prescribe intensity using RIR, the following sections cover how the scale functions for different training goals.

MUSCULAR HYPERTROPHY

Recent investigations into the determinants of muscular hypertrophy have revealed that total volume of training is of primary importance for stimulating muscle growth rather than a specific repetition range (22,37,40,41,47). Although low intensities (~20RM or higher) can produce appreciable hypertrophy (41), if the intensity is too light it may not completely optimize muscle growth. Even when low-intensity (30% 1RM) training is performed until volitional failure, the same degree of muscle activation that occurs with heavier intensities (75% 1RM) is not attained (38). Campos et al. observed that when a matched volume of moderate (9–11RM) and high intensity (3–5RM) training is performed, a similar magnitude of hypertrophy occurs, which is greater than hypertrophy induced by low-intensity training (20–28RM) also performed at a matched volume (8). This may be because light loads, even when forcefully accelerated and matched for volume, do not produce the same force output over the course of a session as moderate loads as indicated by a lower average impulse (27). However, the utility of high repetition low-intensity training for hypertrophy should not be completely dismissed. Recent research compared an equated number of sets at 25–35RM to 8–12RM and found similar levels of hypertrophy (39). Unlike Campos' research, volume (resistance × sets × reps) in the 25–35RM group was approximately twice that of the 8–12RM group, so the comparative utility of high repetition low-intensity training is still in question. However, given the recommendation of some researchers to use a mixture of high, moderate, and low-repetition training to optimize not only global, but fiber-specific hypertrophy (40), a direct comparison between RM training zones might not be the appropriate research question. Rather, future research should examine the utility of a combination of high, moderate, and low RM training zones within a periodized plan because it could prove optimal for maximizing hypertrophy.

To summarize, loads that are "heavy enough" (<20RM) and are performed with an adequately high volume seem to optimize hypertrophy. Thus, for most of the training, both heavy and moderate loads can be used to effectively stimulate muscle growth. However, it seems that the repetition range typically associated with hypertrophy of 6–12 may not be inherently superior to heavier training for hypertrophy for any mechanistic reason (26). Rather, the 6–12 repetition range could potentially have an advantage from a time efficiency stand point. Specifically, data has shown 3RM training to yield similar biceps hypertrophy to 10RM training (40), and undulating periodization of a low-repetition group (2–6 repetitions) versus a high-repetition group (8–12 repetitions) to result in similar hypertrophy of the chest and quadriceps (26); and in both cases, high-repetition training took less total time per session. Performing sets with very heavy loads (3RM) requires substantially longer to perform than matched-volume training with moderate intensities (10RM) (40). Therefore, we advise primarily (but not exclusively) using repetitions in the range of 6–12, with an RIR-based RPE of 8–10 (RIR 0–2) depending on phase of training. Training at an RIR of 0 (to failure) should be implemented in a manner so as not to potentially reduce volume on subsequent sets due to fatigue, and therefore limited to the final set performed for a given body part and primarily relegated to exercises with a low biomechanical complexity and risk of injury (i.e., isolative assistance movements) (22). Thus, for main movements (squats, bench press, etc.) primarily performing sets within the RPE range of 6–8 (i.e., 2–4 RIR) may be an appropriate strategy to avoid excessive muscle damage and reductions in intensity can be implemented as needed on subsequent sets. Likewise, to avoid decrements to volume performed on subsequent sets, rest periods should not be restricted for hypertrophy training despite the common recommendation to do so. With only 1 exception (46), most of the research has not supported the hypothesis that restricted interset rest periods provide an advantage for hypertrophy (1,11,22,24,40). In fact, in one study, a significant increase in hypertrophy was reported only in the group using a longer versus shorter rest interval (7). Indeed, short rest intervals can compromise the volume performed on repeated sets (10), which some authors have theorized could harm hypertrophy and thus subsequent sets should be performed when the athlete is ready (24).

MUSCULAR ENDURANCE

Muscular endurance training is performed in a similar manner as hypertrophy training except with a focus on developing fatigue resistance rather than training to maximize volume at a moderate intensity. In this case, and in contrast to hypertrophy-type training, rest periods can be purposely restricted to promote the adaptation of faster interset recovery if desired (10). Higher repetition training (25–35RM) has been shown to result in a greater number of repetitions performed than hypertrophy training (8–12RM) on the 50% 1RM bench press to failure test (39). Very high repetition training (100–150RM) can also be used to develop muscular endurance, depending on the training goals of the individual, as shown by seminal research by Anderson and Kearney (2). Also, while training to failure is not always advised for hypertrophy because of the potential to harm performance on subsequent sets, training to failure does seem to more effectively enhance local muscular endurance than stopping short of failure (25). Therefore, sets of 12 repetitions and higher (3) performed with shorter rest intervals (<2 minutes) at an RIR-based RPE of 9–10 (RIR 0–1), with rest periods and repetition ranges specific to the needs of the athlete, should constitute most of a session targeting muscular endurance.

MAXIMAL STRENGTH

For the development of strength, it seems that training intensities of 80–100% of 1RM provide the largest mean effect for those with resistance-training experience (32,34). For this reason, it is recommended when training athletes to use intensities in the 1–6RM range for sessions with the goal of maximizing muscular strength (3). When using RIR-based scores, this could translate into a large number of RPE-repetition combinations. As displayed in Table 2, 83% of 1RM is roughly equal to 6RM, therefore 6 repetitions with 0 RIR, 5 repetitions with 1 RIR, 4 repetitions with 2 RIR, or 3 repetitions with 3 RIR would all be roughly equivalent in load and representative of the lower end of the intensity threshold for maximal strength development. However, it is worth repeating the limitations of Table 2 as it is based on the mean values of trained lifters performing the barbell back squat, and thus a perfect relationship between percentage 1RM and RIR should not be expected.

Inherently, the term "maximal strength" is indicative of a performance representative of an athlete's maximal force output. Therefore, per the principle of specificity, some training at an RPE 10 (RIR 0) should occur to acclimate an athlete for this goal, especially if a training cycle is concluded with RM testing. However, caution is advised when training to failure regularly as it may cause alterations in resting hormone concentrations consistent with overreaching in the absence of superior strength enhancement versus submaximal training (i.e., 2 or 1 RIR) (25). In addition, when a large portion of an athlete's training volume is performed to near maximal intensities (i.e., >90% of 1RM), increases in strength may be compromised compared with performing only a moderate amount of volume in this range (18). Thus, training at the higher end of the intensity spectrum should be carefully planned and cycled into a periodized program.

POWER

As was previously stated, determining actual RIR for low intensity high-velocity power training is most likely not possible because of the inability to determine RIR far from failure. However, using an "intensity cap" of RPE 4 could be implemented for low intensity high-velocity power training to ensure movement speed remains appropriately high. Meaning, that if the lifter can accurately estimate RIR, the load is likely inappropriately heavy for this type of training and should be reduced to maintain velocity.

For power training with the goal of developing the high-force end of the power spectrum, the RPE scores determined by RIR may be appropriate. Force-dominant power training using relatively heavy intensities (>80% 1RM) should be performed with maximal intent to accelerate the load while also managing fatigue by performing low repetition sets (1–5) stopping sufficiently short of volitional failure (RIR 2–3) (20,30). Like maximal strength training, rest interval between sets should be adequate to allow for complete recovery and should mostly fall in the range of 3–5 minutes (10).

A visual schematic of the relationship between training goal, repetitions, and RIR-based RPE is shown in Figure 1.

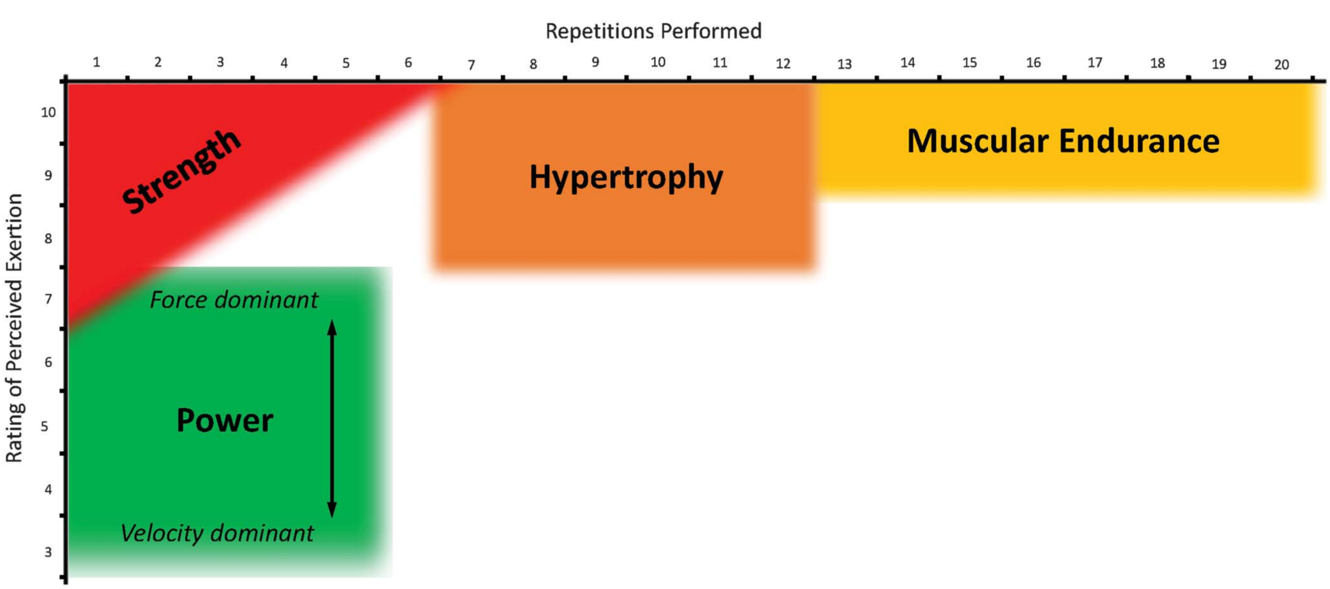

Figure. Relationship of repetitions in reserve–based rating of perceived exertion, repetitions, and training goals.

PRACTICAL APPLICATIONS

The creation of an RIR-based scale is the most recent iteration of RPE that specifically addresses the needs of resistance training. It provides a valid measure of intensity, based on RIR, which retains its reliability when sets are taken near and to volitional failure. While there is a potential advantage in the use of this scale, it should also be pointed out that at this early stage of RIR-based research, a great many questions still remain.

At present, RIR data are available only on novice and experienced male and female lifters performing free weight barbell squats (48) and experienced male lifters performing free weight barbell bench presses and squats (19). Research that specifically examines potential differences between sexes, examines muscle actions other than dynamic (such as eccentric-only training), compares single-joint to multi-joint exercises, machine-based to free weight exercises, and open to closed-chain exercises is lacking at this developmental stage. Although it should not be assumed that the RIR-based scale will prove invalid for comparing males to females or assessing other forms of resistance training, rare differences between sexes (31) and also resistance-training mode (12) have been observed when using traditional RPE that could theoretically extend to an RIR-based scale.

Therefore, while we encourage the appropriate implementation of this scale, until more research is performed, practitioners should be well aware of the limitations of the available research before doing so. For those considering using an RIR-based RPE scale, this article serves to outline its uses, limitations, and how the scale relates to other methods of prescribing intensity such as percentage of 1RM and RM.

It must be stated that this scale is not a stand-alone method of training, however, by following the strategies outlined in this article, this scale can be successfully implemented to prescribe and progress training intensity and load within a periodized model to achieve the desired physiological adaptations.

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