**Repetitions in reserve is a reliable tool for prescribing resistance training load.**

**ABSTRACT**

This study investigated the reliability of repetitions-in-reserve (RIR) as a method for prescribing resistance training load for the deadlift and bench press exercises. Fifteen novice trained males (age: 17.3±0.9 years, height: 176.0±8.8cm, body-mass: 71.3±10.7kg) were assessed for 1-repetition maximum (1RM) for deadlift (118.1±27.3kg) and bench press (58.2±18.6kg). Subsequently, they completed three identical sessions (one familiarization session and two testing sessions) comprising sets of 3-, 5- and 8-reptitions. For each repetition scheme, the load was progressively increased in successive sets until subjects felt they reached 1-RIR at the end of the set. Test-retest reliability of load prescription between the two testing sessions was determined using intraclass-correlation coefficient (ICC) and coefficient of variation (CV). A two-way analysis of variance (ANOVA) with repeated measures was used for each exercise to assess differences in the load corresponding to 1-RIR within each repetition scheme. All test-retest comparisons demonstrated a high level of reliability (deadlift: ICC=0.95-0.99, CV=2.7-5.7% and bench press: ICC=0.97-0.99, CV=3.8-6.2%). While there were no differences between timepoints, there was for load corresponding to 1-RIR across the three repetition schemes (deadlift: 88.2%, 84.3% and 79.2% 1RM; bench press: 93.0%, 87.3% and 79.6% 1RM for the 3-, 5- and 8-repetition sets respectively). These results suggest that RIR is a reliable tool for load prescription in a young novice population. Further, the between repetition scheme differences highlight that practitioners can effectively manipulate load and volume (repetitions in a set) throughout a training program to target specific resistance training adaptations.

**INTRODUCTION**

Autoregulation-based approaches to resistance training prescription are currently the focus of many practitioners and researchers alike (10, 16). These methods have been recommended as a superior alternative to traditional prescription strategies as they account for the unpredictable fluctuations in an individual’s performance capabilities (4). Many autoregulation strategies have been proposed (10, 13, 16), however, there is no consensus on which strategy to use in practice. One novel method of autoregulation, which has been of high interest recently, involves making load adjustments based on the number of additional repetitions an individual believes they could complete prior to reaching muscular failure (repetitions-in-reserve; RIR) (4). When using this method, individuals perform a number of repetitions and sets which are pre-determined based on the desired training stimulus, as is typical of traditional programming (8). Specific load adjustments are then made based on the difference between the RIR rating provided at the immediate conclusion of a set, and the prescribed target RIR. For example, if an individual has been prescribed a target of 2-RIR, yet finished a set with 4-RIR, the load would be increased on the subsequent set (4). The specific load adjustments should be made based on the guidelines for total number of repetitions possible at varied loads. However, as the number of repetitions possible at different loads are highly individualized (23, 27), future research may benefit from quantifying the specific load adjustments required to achieve a target RIR.

A fundamental concept underpinning the method of RIR, is that changes to an individual’s performance capabilities will be reflected in how rapidly they approach muscular failure (10). Put simply, individuals with reduced capabilities would report higher RIR values, and therefore lift a reduced load. The inverse would also likely occur, with individuals reporting lower RIR values and subsequently having positive load adjustments following periods of rapid improvement. Therefore, by prescribing load based of RIR, practitioners are better able to deliver more specific individualized training stimuli comparable to other load-based autoregulation strategies (4).

While it is unclear how different RIR targets impact rates of adaptation and recovery, RIR targets of 1-4 are commonly recommended (9, 18). Using these values allows practitioners to prescribe a high training stimulus, while avoiding the risks and prolonged post-exercise fatigue associated with training to muscular failure (12, 19). Additionally, it has been suggested that practitioners may be able to prescribe different target RIR values over time in order to take a periodized approach to training (9). In fact, it has been recommended that by assigning different target RIR values to each mesocycle, a block periodized approach may facilitate greater strength gains than traditional exercise prescription (4). At this stage however, the reliability of RIR as a load prescription tool has not been established. Investigating the reliability of RIR is essential for ensuring if a specific, rather than variable training dose, could be delivered, the importance of which has been highlighted for other load-prescription strategies (5, 14).

Determining the reliability of RIR-based load prescription not only provides a novel method of autoregulation, it also allows individuals to take a periodized approach to resistance training without the need for a 1-repetition maximum (1RM) assessment. Well-trained populations are still likely to perform 1RM testing to monitor changes in maximal strength (8). However, novice and youth populations, who may not feel comfortable with this assessment due to its maximal nature or who may not have professional supervision, could simply prescribe load based on RIR instead. Current evidence has suggested that resistance training novices are less likely to accurately gauge RIR compared to more experienced individuals (20, 24). However, these studies investigating the influence of training experience on RIR estimation accuracy have conducted all testing within a single session, where subjects may not yet have been as familiarized with RIR estimation protocols as they would in practice. The RIR estimates were also made following repetitions which were distant from muscular failure. Several studies however have highlighted substantially improved RIR estimation accuracy when the estimate is made in close proximity to muscular failure (6, 7, 17). Therefore, the aim for this study was to investigate whether RIR can be used as a reliable tool to prescribe load for two commonly used strength exercises. It was hypothesized that the load corresponding to 1-RIR would exhibit very high test-retest reliability when used for deadlift and bench press sets comprising 3-, 5-, and 8-repetitions.

**METHODS**

**Experimental Approach to the Problem**

Subjects attended the laboratory on four occasions, each separated by 7-days (Figure 1). The first visit was used to determine both deadlift and bench press 1RM, which was used to determine the warm-up loads used in subsequent visits. During the remaining three visits, subjects performed multiple sets using three different repetition schemes (3-, 5-, and 8-repetitions). The order in which each repetition scheme was performed was determined using random sequence generation. For each repetition scheme, progressively heavier loads were used for each subsequent set, until the subjects felt they had reached 1-RIR, as per the RPE/RIR scale (28). Of these three RIR testing sessions, the first was used to familiarize subjects with the RPE/RIR scale and the physical sensations associated with training to different RIR values. The importance of including an anchoring process with perceptual measures has been highlighted in previous research (9). Data from the remaining two RIR testing sessions were used to assess the test-retest reliability of the load corresponding to 1-RIR for each repetition scheme. Between repetition scheme comparisons were also made to ensure load prescription was sensitive to the different demands associated with performing a different number of repetitions within a set.

**Subjects**

Fifteen male resistance training novices (age: 17.6 ± 0.9 years, height: 176.0 ± 8.8 cm, body mass: 71.3 ± 10.7 kg) were recruited for this study and completed the entire protocol voluntarily. All subjects were required to have less than six months resistance training experience. Individuals with a health condition or injury which may be exacerbated by exercise were excluded from this study. Subjects were permitted to continue resistance training throughout the study period, however, they were instructed to refrain from strenuous exercise 48 hours prior to attending the laboratory. The risks and benefits of participation were explained to all subjects and their parents/guardians if under the age of 18 years. Additionally, written consent and medical clearance were provided for all subjects prior to the commencement of any data collection. This study and all its methodologies were approved by the institutional human research ethics committee (SMEC\_2016-17\_047).

**Procedures**

*One Repetition Maximum Testing*

One week prior to the familiarization session, participants had their height and body mass recorded and completed a baseline 1RM assessment for the deadlift and bench press (8). Briefly, subjects completed an exercise specific warm-up comprising 5-repetitions of 20% of estimated 1RM, 3-repetitions at 50% 1RM, 2-repetitions at 75% 1RM and 1-repetition at 85% 1RM, with 2 minutes of passive rest between sets. The load was then increased by ~2.5-5% for 3-6 progressively heavier single repetitions sets until the subjects were unable to register a successful repetition. Subjects rested for 3-minutes between attempts to minimise the influence of fatigue, with the heaviest load lifted by the subject being recorded as their 1RM.

A deadlift repetition was deemed unsuccessful if the subject was unable to lock the knees while standing fully erect with retracted shoulders. Similarly, for the bench press, subjects were required to fully extend the elbows while the posterior aspects of the head, shoulders and hips remained in contact with the bench. The deadlift was performed prior to the bench press on all occasions, with subjects resting for 5-minutes between exercises. A 20kg Olympic barbell (Strength Shop, UK), solid black Olympic bumper plates and fractional plates down to 0.5kg were used (Strength Shop, UK), allowing a minimum 1kg between loads The RPE/RIR scale was introduced to the participants during the assessment session with appropriate anchoring procedures (9, 28). After each lift of the 1RM attempt, subjects were asked to assign the load an RIR score based on the RPE/RIR scale (9), effectively familiarizing them with the physical sensations associated with different RIR values. Clear and consistent verbal encouragement was provided for all repetitions in this study to ensure reliable subject effort (26).

*Familiarization and RIR Testing Sessions*

During the familiarization session and the two RIR testing sessions the deadlift was always performed before the bench press. Initially, subjects completed 8-repetitions with 20% 1RM. They then completed a series of progressively heavier sets with 3-, 5- and 8-repetitions in a randomised order. Randomising the order of each repetition scheme was a key methodological consideration in this study as it ensured recency bias did not influence the previous RIR scores provided by each subject. The initial set for each repetition scheme was 75%, 70% and 65% 1RM for the 3-, 5- and 8-repetition schemes respectively. Subjects were instructed to use the RPE/RIR scale and provide a verbal note of the specific RIR scores associated with each set. The United Kingdom Strength and Conditioning Association accredited coach, who was present during all testing sessions, determined the load increase between sets, based on the RIR score provided by the subject (4). In line with previous research (4), the current recommendations for the number of maximal repetitions possible and the load used (8), were consulted when determining the specific load adjustments to be made between sets. The incrementally heavy sets were continued for each repetition scheme until the subject reported 1-RIR, for which the specific load achieved was recorded by the research team. Subjects rested for 3-minutes between sets comprising the same number of repetitions and for 5-minutes between repetition schemes. An additional 10-minutes of rest was provided to subjects between RIR assessments for the deadlift and bench press. To ensure subjects did not pre-empt RIR scores prior to performing each set, they were instructed to leave the room briefly when load adjustments were made. While subjects were able to see the load to be lifted upon returning to the room, recent research has recently confirmed that blinding subjects to the load being lifted has a negligible effect on the RIR scores provided (17).

\*\*INSERT FIGURE 1 NEAR HERE\*\*

***Statistical Analysis***

The mean SD was calculated for the load corresponding with 1-RIR for 3-, 5- and 8-repetition sets, for both the deadlift and bench press exercise. The test-retest reliability of this load prescription method was determined using intraclass correlation coefficients (ICC: model 3, form 1) and coefficient of variation (CV%) with 95% confidence intervals (11). Reliability was classified; good (ICC >0.67 and CV <10%), moderate (ICC >0.67 or CV <10% but not both), and poor (ICC <0.67 and CV >10%). Additionally, a two-way analysis of variance (ANOVA) with repeated measures was used for each exercise to assess differences in the load corresponding to 1 RIR with each repetition scheme using a 3 x 2 design (repetition scheme x time). Given that sphericity was violated for this analysis in both exercises, Greenhouse-Geisser correction procedure was used. Bonferroni post hoc corrections were also used, and statistical significance was set at ≤ 0.05. These analyses were performed using the Statistical Package for Social Sciences software (SPSS v.22, IBM, New York, USA). Additionally, effect sizes (hedges *g*) were calculated to evaluate the size of both test-retest differences and between-repetition scheme differences in the load corresponding with 1-RIR. These effect size estimates were compared to determine if this method of load prescription could be used to assign a precise training stimulus. Resistance training specific thresholds, designed for a novice population, were used to interpret these effect size scores (trivial < 0.50, small: 0.50-1.25, moderate: 1.25-1.9, large: ≥ 2.0) (21).

**RESULTS**

Mean 1RM for the deadlift and bench press were 118.1 ± 27.3 kg (1.7 ± 0.3 1RM [kg] / bodyweight [kg]) and 58.2 ± 18.6 kg (0.8 ± 0.2 1RM [kg] / bodyweight [kg]) respectively. Table 1 presents the test-retest reliability of the load corresponding to 1-RIR for 3-, 5- and 8-repetition deadlift and bench press sets. All test-retest comparisons demonstrated a high level of reliability. There was no interaction effect for either deadlift (*p =*0.701) or bench press (*p =* 0.129). There was no main effect for time with either the deadlift (*p =* 0.092, *g* = 0.09-0.16), or bench press (*p =* 0.776, *g* = 0.04-0.05). There was however, a main effect for the repetition scheme observed for both deadlift (*p* < 0.001, g = 0.32-0.74) and bench press (*p* < 0.001, g = 0.31-0.76), highlighting that for sets comprising 3-, 5- and 8-repetitions, there are different loads which correspond to 1-RIR. For the deadlift, 1 RIR corresponded to loads of 88.2%, 84.3% and 77.2% 1RM, for 3-, 5- and 8-repetition sets respectively. For the bench press, loads of 93.0%, 87.3% and 79.6% 1RM corresponded to 1-RIR for sets of 3-, 5- and 8-repetition sets respectively.

\*\*INSERT TABLE 1 NEAR HERE\*\*

**DISCUSSION**

This study assessed whether RIR could be used as a reliable load prescription tool in a novice youth population. The main findings of this investigation indicate; 1) the load corresponding to 1-RIR is highly reliable for deadlift and bench press sets comprising the same number of repetitions, and 2) different loads correspond to 1-RIR in sets which comprise a different number of repetitions. These results suggest that RIR can be used as a reliable tool to prescribe load for both the deadlift and bench press.

The high ICCs and low CVs of this study highlight that the RIR method results in reliable load prescriptions at a given RIR target (1-RIR) for three different %1RM loads in both lower and upper body exercises. Overall, using a target of 1-RIR will result in reliable load prescription between sessions. This is essential as it ensures that individuals using this method experience a controlled and specific training stimulus (1, 2). Importantly, in resistance training novices, this method of load prescription may be less variable than traditional 1RM based load prescription (2). Previous research has highlighted that due to a lack of experience in lifting maximal loads, this population often require multiple 1RM assessments to be conducted before a reliable 1RM can be obtained (2). This process is highly time consuming (1) and would need to be replicated for each exercise being implemented in the training program (8). In fact, Bocalini et al (2) reported that it would likely take over six testing sessions to obtain a reliable 1RM with this population, possibly delaying the start of a training program for 3-6 weeks. Prescribing load based on RIR may therefore be a time-saving, superior alternative to prescribing loads based with 1RM in novice populations.

Additionally, using RIR, rather than 1RM to prescribe load, may allow practitioners to account for fluctuations in an individual’s strength levels (4, 10). It has previously been noted, that if loads are prescribed based on a pre-determined 1RM value, and individuals are fatigued or have adapted rapidly, the training demands are likely to be excessive or insufficient (13, 25). This may result in an increased risk of overtraining and injury (15), or conversely, a stimulus which is insufficient to produce the desired adaptations (8). When using RIR to prescribe load however, individuals experiencing reduced strength would report lower RIR scores for a given set, resulting in a reduced load being used. Equally, individuals whose strength levels have adapted rapidly would report higher RIR scores and lift an increased load. Previous research employing this method of load prescription in a well-trained population demonstrates that it results in more rapid improvement in strength compared with traditional 1RM-based prescription (6). In a young, novice population autoregulatory methods of load-prescription, such as RIR, may be even more beneficial as strength often develops rapidly(2) and recovery rates are highly unpredictable (3).

Importantly, different loads were associated with 1-RIR in sets comprising a different number of repetitions. These results concur with previous work highlighting that there is a strong relationship between relative load and the number of repetitions possible prior to reaching muscular failure (23). Considering resistance training adaptations are load dependant (22), this is an important finding as it enables practitioners to vary the load across a training program. Furthermore, this allows practitioners to use RIR-based load prescription to take a periodized approach to training (4). For example, individuals could be prescribed sets of 8-repetitions at 1-RIR followed by 5-repetitions at 1-RIR and 3-repetitions at 1-RIR over three consecutive mesocycles. This would result in a progressive increase in load and decrease in volume, similar to that seen in commonly used periodisation methods.

Overall the current study provides evidence to suggest RIR-based load prescription may allow practitioners to take a periodized approach to resistance training, while simultaneously accounting for unpredictable changes in an individual’s strength capabilities. It is important to acknowledge that prescribing loads based on a target of 1-RIR will always result in a near maximal effort (i.e 1-repetition short of failure)(18). While this study provides additional information to the practical usefulness of RIR as a means of load prescription, it is not without limitations. Recent research has suggested that 1RM in an untrained population may in fact be more stable than previously suggested in earlier research (5). We acknowledge that during the 4-week period in which subjects completed this study, it is possible that there was some small variation in the maximal strength levels of each individual. However, given that these session-to-session variations also occur consistently in a practical setting and often go undetected it is unlikely that this would have any meaningful impact on the results of the current study. Further, while it seems likely that practitioners could vary training effort by using different RIR targets (i.e 2-RIR), the reliability of using different RIR targets for load prescription has yet been determined. This is therefore an important direction for future research, particularly considering there is evidence to suggest individuals become worse at estimating RIR the further they are from muscular failure (27).

**PRACTICAL APPLICATIONS**

The results of this study indicate that practitioners can use a target of 1-RIR to prescribe the loads to be lifted within a resistance training program. Additionally, in a young, resistance training novice population this method of load prescription may be a superior alternative to prescribing load based on 1RM. By prescribing loads based on a target of 1-RIR rather than 1RM, practitioners may avoid the need for multiple 1RM assessment sessions. Instead, this time can be dedicated to resistance training sessions themselves, which would serve to greater improve the desired training adaptations. Further, this method of load prescription accounts for unpredictable fluctuations in an individual’s strength capabilities. This may optimize training adaptations, by ensuring the stimulus experienced is appropriate for an individual’s ability to perform resistance training on a given day. We recommend practitioners implement RIR-based load prescription in a periodized manner, by manipulating the number of repetitions to be performed (and subsequently the load) over successive mesocycles. For example, progressing from 8-repetitions to 5-repetition to 3-repetitions with a load corresponding to 1-RIR, would result in a gradual increase in load and reduction in training volume over the course of a training program. As of yet, practitioners should be cautioned against using higher RIR targets, such as 2-RIR, for load prescription, as the reliability of using these targets remains unknown.

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**Table 1**: Test-retest reliability of the load corresponding to 1 RIR for sets comprising 3-, 5- and 8-repetitions

§‡

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Deadlift | | Bench Press | |
|  | ICC (95% CI) | CV (95% CI) | ICC (95% CI) | CV (95% CI) |
| 3-repetitions | 0.98 (0.93-0.99) | 3.5% (2.5-5.6) | 0.99 (0.96-1.00) | 3.8% (2.7-6.0) |
| 5-repetitions | 0.99 (0.96-1.00) | 2.7% (2.0-4.3) | 0.98 (0.95-0.99) | 4.0% (2.9-6.4) |
| 8-repetitions | 0.95 (0.85-0.98) | 5.7% (4.1-9.1) | 0.97 (0.90-0.99) | 6.2% (4.5-9.9) |

ICC = Intraclass correlation coefficient, CV = Coefficient of variation, CI = Confidence intervals

**LIST OF FIGURES**

**Figure 1.** Schematic representation of the experimental protocol including the protocol completed by subjects in each session.

**\***Loads used for initial 1RM assessments based on 1RM estimates made by the United Kingdom Strength and Conditioning Association accredited strength coach in consultation with each individual subject

X = The number of incrementally heavy sets required, before individuals verbalised that they had reached 1-RIR for that specific repetition scheme.