

## Self-rated Accuracy of Rating of Perceived Exertion-based Load Prescription in Powerlifters

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**1 Abstract**

2 This study assessed male (n=9) and female (n=3) powerlifters' (18-49yrs) ability to select loads  
3 using the repetitions in reserve (RIR)-based rating of perceived exertion (RPE) scale for a single  
4 set for squat, bench press and deadlift. Subjects trained 3x/wk. for 3wks. on non-consecutive  
5 days in the weekly order of hypertrophy (8-repetitions at 8 RPE), power (2-repetitions at 8 RPE),  
6 and strength (3-repetitions at 9 RPE), using subject-selected loads intended to match the target  
7 RPE. Bench press and squat were performed every session and deadlift during strength and  
8 power only. Mean absolute RPE differences ( $|\text{reported RPE} - \text{target RPE}|$ ) ranged from 0.22-  
9 0.44, with a mean of  $0.33 \pm 0.28$  RPE. There were no significant RPE differences within-lifts  
10 between sessions for squat or deadlift. However, bench press was closer to the target RPE for  
11 strength ( $0.15 \pm 0.42$  RPE) vs. power ( $-0.21 \pm 0.35$  RPE,  $p=0.05$ ). There were no significant  
12 differences within-session between lifts for power and strength. However, bench press was closer  
13 ( $0.14 \pm 0.44$  RPE) to the target RPE than squat ( $-0.19 \pm 0.21$  RPE) during hypertrophy ( $p=0.02$ ).  
14 Squat power was closer to the target RPE in week 3 ( $0.08 \pm 0.29$  RPE) vs 1 ( $-0.46 \pm 0.69$  RPE,  
15  $p=0.03$ ). It seems powerlifters can accurately select loads to reach a prescribed RPE. However,  
16 accuracy for 8-repetition sets at 8 RPE may be better for bench press compared to squat. Rating  
17 squat power-type training may take 3wks. to reach peak accuracy. Finally, bench press RPE  
18 accuracy appears better closer rather than further from failure (i.e. 3-repetition 9 RPE sets vs. 2-  
19 repetition 8 RPE sets).

20

21 **Key Words: resistance training, autoregulation, powerlifting, periodization, load**  
22 **prescription.**

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## 26 INTRODUCTION

27 It has been reported that there is a wide disparity of repetitions allowed at various  
28 percentages of one-repetition maximum (1RM) among individuals (7) and large fluctuations of  
29 resistance training performance based upon daily readiness (5, 9). Thus, the repetitions in reserve  
30 (RIR) –based rating of perceived exertion (RPE) scale (11) was designed to autoregulate training  
31 load based upon daily readiness (3), and equate effort per set across individuals. Therefore,  
32 instead of prescribing a number of repetitions at a particular percentage of 1RM, a number of  
33 repetitions can be prescribed with a target RPE i.e. 8 repetitions at an 8 RPE (2 RIR).

34 The RIR-based scale has specific utility because less than maximal Borg RPE ratings are  
35 sometimes given by subjects even when performing sets to failure (2); in contrast the RIR-based  
36 scale seems especially accurate when training near to failure. Importantly, it was demonstrated  
37 that trained males and females estimated RIR accurately (an RIR error of  $< 1$ ) when performing  
38 sets 0-3 repetitions from failure with a predetermined load (1) however, RIR was less accurate  
39 when performing sets further from failure (1, 2). Additionally, RPE/RIR accuracy has been  
40 shown to improve with training experience (3). However, there is no study examining the  
41 accuracy of self-selected loads (i.e. no predetermined load) to comply with the desired RPE.

42 Therefore, the aim of this study was to assess nationally qualified male and female  
43 powerlifters' ability to accurately select loads resulting in a target RIR-based RPE for a single set  
44 in the squat, bench press and deadlift on hypertrophy-, power- and strength-type sessions over  
45 three weeks. We hypothesized accuracy would be the same between lifts, as similar RPE has  
46 been previously reported among the powerlifts at 1RM in powerlifters (4). Additionally, we  
47 hypothesized accuracy during lower RPE hypertrophy and power sessions (target RPE = 8)  
48 would be less than the higher RPE strength sessions (target RPE = 9). Finally, we postulated

49 accuracy would improve over three weeks as subjects gained familiarity with this training  
50 approach.

## 51 **METHODS**

### 52 **Experimental Approach to the Problem**

53 Competitive powerlifters performed the squat and bench press 3x/wk. and the deadlift  
54 2x/wk. (only strength and power sessions) for three weeks in a daily undulating format. Weekly  
55 session order was hypertrophy-, power-, then strength-type on non-consecutive days (i.e. Mon.,  
56 Wed., Fri.) (10). Immediately before an initial 1RM testing session, which occurred 72 hours  
57 prior to the first training session, the RIR-based RPE scale was shown to each participant and  
58 described in detail (11). The scale was shown to subjects following all warm-up and working sets  
59 during testing.

60 During training, an RPE target was provided for a specific number of repetitions on the  
61 initial working set for each lift; thus, subjects self-selected the load they believed would result in  
62 the target RPE. Only the load for the initial set was selected by the participants (subsequent sets  
63 were adjusted based on post-set RPE score). Therefore, to determine RPE accuracy, differences  
64 between the target RPE and actual RPE after the initial set for each exercise were analyzed.

### 65 **Subjects**

66 Fourteen powerlifters were recruited and twelve completed the protocol; nine males  
67 (height  $1.71 \pm 0.06\text{m}$ ; body mass  $81.9 \pm 12.5\text{kg}$ ) and three females (height  $1.62 \pm 0.08\text{m}$ ; body  
68 mass  $59.0 \pm 5.8\text{kg}$ ). Two (male:  $n=2$ ) dropped out due to injury or inability to complete all  
69 sessions. Inclusion criteria was as follows: 1) minimum resistance training experience 1 yr; 2)  
70 meeting the New Zealand powerlifting national qualifying strength requirements in prior  
71 competition (within one year) or during testing (6); 3) compliance with the banned substance list

72 of the International Powerlifting Federation (IPF) (8); 4) be between 18-49yrs old; and, 5) be free  
73 from injury/illness. All subjects were informed of potential risks and signed an informed consent  
74 document prior to participation (University ethics approval number 15/06).

## 75 **Procedures**

76 *Rating of Perceived Exertion.* The RIR-based RPE scale (i.e. RPE scores which  
77 correspond to RIR) (Figure 1) (11) was used throughout the study. The scale was shown and  
78 explained to each subject in the same exact manner prior to pre-testing and was shown to each  
79 subject following all warm-up and working sets.

80 INSERT FIGURE 1 HERE

81 *Training Protocol.* Three weeks of training were completed with a program similar to a  
82 previous undulating powerlifting protocol (10) in that each session had a specific goal: Monday:  
83 “hypertrophy” (8-repetitions at an 8 RPE), Wednesday: “power” (2-repetitions at an 8 RPE) and  
84 Friday: “strength” (3-repetitions at a 9 RPE). The squat and bench press were performed in all  
85 sessions, while deadlift was performed only on power and strength sessions to minimize injury  
86 risk and to comply with common powerlifting methods. Subjects were trained in the “offseason”,  
87 i.e. they were not in the immediate pre-competition training phase. Subjects were instructed to  
88 not modify their nutrition or nutritional supplementation during the study and all sessions for  
89 each individual were carried out at the same time of day whenever possible. In each session, lifts  
90 were performed in competition order: squat, then bench press and then deadlift (if performed),  
91 following a dynamic warm-up and warm-up sets. There was a 5-minute rest period after the  
92 completion of a lift before the next was initiated. After each warm-up set RPE was obtained, and  
93 after all warm-up sets the subject was informed of the repetition and RPE target for the day.  
94 Following warm-up sets, a 3-minute rest was administered, then subjects performed the working

95 set with a self-selected load with the goal of meeting the target repetitions and RPE. Consultation  
96 of prior session data was allowed to assist load selection.

97

## 98 **Statistical Analyses**

99 To quantify the directionality of error, 'RPE difference' (RPEDIFF) of target versus  
100 reported RPE was recorded (reported RPE score - RPE target). Thus, negative numbers represent  
101 'undershooting' target RPE, while positive represent an 'overshoot'. Since RPE corresponds to  
102 RIR, missed repetitions counted as a full RPE score overshoot. This data is displayed in Figure 2.

103 To display 'absolute accuracy', the mean absolute RPEDIFF (negative sign excluded for  
104 RPE undershoot) for each lift for each session was calculated. Thus, absolute RPEDIFF values  
105 were averaged for squat hypertrophy week 1, 2 and 3, bench press power week 1, 2 and 3,  
106 deadlift strength week 1, 2, and 3 etc., for each subject. This data is displayed in Table 1.

107 Non-parametric statistical comparisons were made using RPEDIFF values (sign  
108 included). Both RPEDIFF over and undershoot values were averaged to generate means so that  
109 differences in directionality (under and overshooting) of accuracy could be assessed.  
110 Comparisons were made from each week, for each lift, for the same training session compared to  
111 the other lifts (i.e. squat hypertrophy vs. bench press hypertrophy). Additionally, comparisons  
112 were made within the same lift, between training sessions (i.e. bench press hypertrophy vs. bench  
113 press power vs. bench press strength). Finally, comparisons were made between weeks for the  
114 same lift, during the same session to assess the effect of time (i.e. deadlift power week 1 vs  
115 deadlift power week 2 vs deadlift power week 3).

116 A Friedman test with an alpha set at 0.05 was used for comparisons between two  
117 variables (i.e. squat and bench press comparisons on hypertrophy sessions). When three variables

118 were compared (i.e. hypertrophy vs. power vs. strength for the bench press), a Friedman test  
119 followed by a post hoc Wilcoxon signed rank test was used. A Bonferonni correction was used  
120 for three variable comparisons. Analysis was performed using a statistical software package  
121 (IBM SPSS Statistics 21, SPSS Inc., Chicago, IL).

122

## 123 **RESULTS**

### 124 **RPE ‘Under’ and ‘Overshoot’**

125 Figure 2 displays RPEDIFF without the sign dropped to demonstrate RPE ‘over’ and  
126 ‘undershoot’ throughout the study with ‘X’ values displaying RPEDIFF among individual  
127 subjects (darker x’s signify a greater number of subjects with the same RPEDIFF).

128 INSERT FIGURE 2 HERE

### 129 **Absolute RPEDIFF Scores**

130 Table 1 displays RPEDIFF values, with the sign dropped, for the group and individuals to  
131 show ‘absolute accuracy’.

132 INSERT TABLE 1 HERE

### 133 **Within-lift RPEDIFF Comparisons between Sessions**

134 Squat RPEDIFF comparisons between hypertrophy ( $-0.19 \pm 0.21$  RPE), power ( $-0.10 \pm$   
135  $0.45$  RPE) and strength ( $0.01 \pm 0.37$  RPE) sessions were not significantly different (raw  $p = 0.07$   
136 to  $0.76$ ; Bonferroni corrected  $p = 0.22$  to  $0.99$ ). Bench press RPEDIFF for hypertrophy ( $0.14 \pm$   
137  $0.44$  RPE) was closer to the RPE target compared to power ( $-0.21 \pm 0.35$  RPE), but this  
138 difference only approached significance after ad hoc testing (raw  $p = 0.03$ ; Bonferroni corrected  
139  $p = 0.10$ ). Bench press RPEDIFF for strength ( $0.15 \pm 0.42$  RPE) was significantly closer than  
140 power to the target RPE (raw  $p = 0.02$ ; Bonferroni corrected  $p = 0.05$ ). Bench press RPEDIFF

141 for strength vs. hypertrophy were not significantly different (raw  $p = 0.94$ ; Bonferroni corrected  
142  $p = 0.99$ ). Finally, deadlift RPEDIFF for strength ( $0.04 \pm 0.41$  RPE) was not significantly  
143 different than power ( $-0.08 \pm 0.23$  RPE,  $p = 0.16$ ).

#### 144 **Within-session RPEDIFF Comparisons between Lifts**

145 Bench press RPEDIFF was closer to the RPE target compared to squat on hypertrophy  
146 sessions ( $p = 0.02$ ). All comparisons of RPE differences during power sessions among the lifts  
147 were non-significant (raw  $p = 0.17$  to  $0.72$ ; Bonferroni corrected  $p = 0.50$  to  $0.99$ ). Likewise, all  
148 comparisons of RPE differences during strength sessions among the lifts were non-significant  
149 (raw  $p = 0.58$  to  $0.81$ ; Bonferroni corrected  $p = 0.99$ ).

#### 150 **RPEDIFF over Time**

151 To assess whether the accuracy of load selection to reach RPE targets changed over time,  
152 RPEDIFF was assessed across weeks. There was a difference approaching statistical significance  
153 indicating that week-3 ( $-0.04 \pm 0.26$  RPE) vs. week-1 ( $-0.33 \pm 0.39$  RPE) accuracy may have  
154 improved during squat hypertrophy sessions (raw  $p = 0.04$ ; Bonferroni corrected  $p = 0.11$ ).  
155 Likewise, a difference approaching significance indicated that week-2 ( $0.08 \pm 0.67$  RPE) vs.  
156 week-1 ( $-0.46 \pm 0.69$  RPE) accuracy may have improved for squat in power sessions (raw  $p =$   
157  $0.03$ ; Bonferroni corrected  $p = 0.09$ ). Week-3 RPEDIFF for squat in power sessions ( $0.08 \pm 0.29$   
158 RPE) was significantly more accurate vs. week-1 (raw  $p = 0.01$ ; Bonferroni corrected  $p = 0.03$ ).  
159 All other comparisons across weeks did not approach nor reach significance after Bonferroni  
160 correction.

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162

163



164 **DISCUSSION**

165           The purpose of this investigation was to assess if powerlifters could accurately self-select  
166 loads corresponding to a target RPE and number of repetitions. Our first hypothesis, that  
167 RPEDIFF would be similar between lifts, was mostly supported in that the comparisons were  
168 non-significant during strength and power sessions. However, RPE scores for bench press were  
169 closer to the target RPE than squat during hypertrophy sessions ( $p = 0.02$ ). Our second  
170 hypothesis, that RPE scores during strength sessions would be closer to the target (RPE 9) than  
171 hypertrophy and power sessions (RPE 8), was mostly unsupported as the accuracy of strength  
172 session RPE was only statistically superior to power for the bench press (Bonferroni corrected  $p$   
173  $= 0.05$ ). Finally, our premise that reported RPE would be closer to the target over time as  
174 accuracy improved, was only true for squat hypertrophy sessions in week three vs. week one  
175 (Bonferroni corrected  $p = 0.03$ ).

176           A potential explanation for why RPE was closer to the target for bench press compared to  
177 squat during hypertrophy sessions, is that squats arguably require more technical skill and  
178 generate more systemic fatigue due to the amount of musculature involved. Thus, there is a  
179 greater chance of a technique error, causing greater RPE variability, with high repetition squats  
180 compared to the bench press. To reconcile our second hypothesis being unsupported, Hackett  
181 and colleagues recently reported RIR to be accurately estimated when repetitions were within 0-  
182 3 of failure (1, 2), which would encompass all present target RPEs (8-9 RPE = 1-2 RIR).  
183 Regarding our final hypothesis of improvement over time with RPE, statistically there was only  
184 an improvement in the squat during power sessions (week 2 vs. 1, Bonferroni corrected  $p = 0.09$ ;  
185 week 3 vs. 1, Bonferroni corrected  $p = 0.03$ ). Although, there was also a trend for improvement  
186 during squat hypertrophy sessions (week 3 vs. 1, Bonferroni corrected  $p = 0.11$ ). As previously

187 stated, the squat arguably requires the most technical proficiency to perform. This, combined  
188 with lower target RPE on power and hypertrophy sessions relative to strength sessions, may be  
189 why a learning effect was observed only when a lower RPE was combined with the most  
190 complex lift. However, it can be observed from the data in Figure 2 (panels A, B and C) that the  
191 spread of RPE scores tightened around the target as the lifters progressed from weeks 1 to 3, with  
192 the exception of two outlier performances in week 3. Additionally, it is possible that 3 weeks is  
193 not a long enough time frame to demonstrate improvements in RPE accuracy.

194 Overall, accurate loads were selected to reach the target RPE. Even when extending  
195 absolute RPEDIFF two SDs from the mean, values were ~1 RPE from the target on average  
196 (Table 1). However, limitations do exist: sets were not performed to failure (except in error when  
197 exceeding the target RPE) thus, whether RPE scores represented 'true' RIR is unknown; however,  
198 it has previously been reported that intra-set RIR ratings were accurate when sets were close to  
199 failure (1, 2). Finally, accuracy was only examined in one set, thus future research should  
200 examine the ability to meet an RPE target with a self-selected load on subsequent sets once  
201 fatigue (neuromuscular and metabolic) is present.

202

### 203 **PRACTICAL APPLICATIONS**

204 Powerlifters can select loads to reach a self-rated target RPE with precision after a  
205 familiarization session explaining and using the RPE scale. However, achieving peak accuracy  
206 levels for the squat at RPE targets below 9 may require at least three weeks. Additionally, it  
207 seems that RPE ratings for the bench press are more accurate when performing low repetition  
208 sets closer to failure, and powerlifters are slightly better at selecting a load for an RPE target with  
209 high repetitions (8-repetitions at RPE 8) in the bench press vs. squat. However, the between lift

210 difference magnitude is low in that on average, powerlifters had an absolute error of 0.33 RPE,  
 211 with a mean range of 0.22-0.44 RPE (Table 1). Thus, practical differences in accuracy between  
 212 lifts and sessions may be inconsequential. Practically, we recommend that RPE targets can be  
 213 used for load prescription in powerlifters however, it is unknown if untrained lifters can  
 214 effectively self-select a target RPE load.

215 **Table and Figure Legend:**

216 **Table 1. 3-week average absolute RPEDIFF values.**

217 **Figure 1. RIR-based RPE scale**

218 **Figure 2. RPEDIFF values of powerlifters performing the squat, bench press and deadlift**  
 219 **over 3 weeks.**

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ACCEPTED

Table 1. 3-week average absolute RPEDIFF values

Subject number	Squat hypertrophy	Squat power	Squat strength	Bench press hypertrophy	Bench press power	Bench press strength	Deadlift power	Deadlift strength	Combined averages
1	0.33	0.00	0.17	0.50	0.33	0.50	0.33	0.00	0.27
2	0.00	0.50	0.17	0.00	0.17	0.50	0.17	0.50	0.25
3	0.33	0.00	0.33	0.00	0.00	0.33	0.33	0.00	0.17
4	0.17	0.50	0.33	1.17	1.00	0.83	0.00	0.50	0.56
5	0.33	0.33	0.17	0.17	0.50	0.33	0.50	0.83	0.40
6	0.17	0.17	0.17	0.50	0.17	0.00	0.17	0.17	0.19
7	0.17	0.17	0.00	0.50	0.00	0.00	0.17	0.17	0.15
8	0.50	0.17	0.33	1.33	0.50	1.00	0.33	0.33	0.56
9	0.17	0.17	0.17	0.33	0.17	0.33	0.17	0.00	0.19
10	0.33	0.50	0.33	0.33	0.17	0.33	0.17	0.83	0.38
11	0.00	0.83	0.67	0.17	0.17	0.33	0.17	0.00	0.29
12	0.50	0.83	1.00	0.33	1.00	0.67	0.17	0.17	0.58
Mean	0.25	0.35	0.32	0.44	0.35	0.43	0.22	0.29	0.33
SD	0.17	0.29	0.27	0.42	0.34	0.30	0.13	0.31	0.28

Absolute RPEDIFF = reported RPE - target RPE with sign dropped.

Values are the 3-week average of each subject's absolute RPEDIFF score for the listed lift and session.

## Resistance Exercise-Specific Rating of Perceived Exertion (RPE)

<b>Rating</b>	<b>Description of Perceived Exertion</b>
<b>10</b>	<b>Maximum effort</b>
<b>9.5</b>	<b>No further repetitions but could increase load</b>
<b>9</b>	<b>1 repetition remaining</b>
<b>8.5</b>	<b>1-2 repetitions remaining</b>
<b>8</b>	<b>2 repetitions remaining</b>
<b>7.5</b>	<b>2-3 repetitions remaining</b>
<b>7</b>	<b>3 repetitions remaining</b>
<b>5-6</b>	<b>4-6 repetitions remaining</b>
<b>3-4</b>	<b>Light effort</b>
<b>1-2</b>	<b>Little to no effort</b>

