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Relationship between the rating of perceived exertion scale and the load intensity of resistance training

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Abstract

Studies have reported that the load intensity of Resistance training is related to the rating of perceived exertion scale in healthy subjects. The aim of our column was to evaluate current evidence regarding the relationship between the rating of perceived exertion scale and the load intensity of resistance training.

INTRODUCTION

Resistance training (RT) is an important component of rehabilitation training programs. RT is a type of physical exercise involving the use of resistance to produce muscular contractions, and is used to improve the strength and size of skeletal muscles. RT is often defined in terms of the total volume of load lifted (sets $\times$ repetitions $\times$ load) during each session(16, 45). The National Strength and Conditioning Association recommends RT consisting of 6-12 repetitions at 67-85% of 1-repetition maximum (1RM) for healthy people to increase muscular strength (4). 1RM is a popular metric for assessing muscular strength during rehabilitation(47, 73), and is defined as the maximal weight that a subject can lift for one repetition. However, determining 1RM is not always feasible in the context of rehabilitation because specialized strength equipment is required, and it is therefore often difficult to determine 1RM in the gym, rehabilitation clinic, or nursing home in which the session is being performed.

Recently, many studies have reported a relationship between the rating of perceived exertion (RPE) and % 1RM (40, 55, 67). RPE provides a means for RT to be performed without the use of specialized RT machines. The purpose of this review article was to analyze the

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current literature regarding the relationship between RPE and the load intensity of RT to determine whether RPE can replace machinery-based measurements in a rehabilitative setting.

RPE is a subjective, self-performed rating of the intensity of exercise based on the patient's perception of physical exertion. RPE is commonly used to monitor the intensity of aerobic exercise. RPE scores can be used to gauge the patient's level of intensity during training, ensuring a safe intensity based on the patient's perception. Perceived exertion takes into account a number of factors associated with exercise intensity, such as heart rate and breathing rate. The Borg 15-point RPE scale(6, 8) and Borg category ratio (Borg CR-10)(7) are often used to measure RPE because they are simple methods. More recently, the OMNI resistance exercise scale (OMNI-RES) has also been used to assess RPE during RT.

The Borg 15-point RPE scale, Borg CR-10, and OMNI-RES are described in the sections that follow.

Borg 15-point RPE scale

The Borg 15-point RPE scale was developed by Borg(6). The scale is a modified 6–20-point RPE scale (Table 1). The Borg 15-point RPE scale is used to measure the level of physical strain or perceived exertion(8). The Borg 15-point RPE scale has been shown to be significantly correlated with heart rate. Moreover, this scale is considered a valid and inexpensive tool for monitoring exercise intensity (68). In clinical practice, patients are instructed to choose a number from the scale and rate their overall effort during RT. A rating of 6 is considered to represent no exertion, i.e. rest, and a rating of 20 represents maximal exertion, i.e. the most stressful exercise performed.

Borg category ratio (Borg CR-10)

The Borg CR-10 Scale is more useful than the Borg 15-point RPE scale on which it was based(5, 7). The scale is presented in Table 2. After completing each working set, the subjects are asked to rate their perceived exertion level by choosing a number from the scale. On this scale, a rating of 0 represents no effort, i.e. rest, and a rating of 10 represents maximal effort, i.e. the most stressful exercise performed.

OMNI-resistance exercise scale (OMNI-RES)

The OMNI-RES was developed by Robertson *et al.* as a substitute for the Borg RPE scales(66). This scale is presented in Figure 1. Subjects are instructed to use a number from the scale to rate their overall muscular effort level, and the investigator asks the patient “How hard do you feel your muscles are working?” An anchoring procedure is included in which the subject assigns the perceived level of exertion associated with lifting a very light weight as ‘Extremely easy’ and the feeling of exertion associated with lifting a very heavy weight as ‘Extremely hard’. Subjects are then instructed to report their RPE at the end of RT using a number from the OMNI-RES (0–10) scale(66). On the scale, a score of 0 represents maximal rest (i.e., a seated position), and 10 represents a sensation of effort above that which the patient could feel during the session.

Studies of the relationship between RPE and the load intensity of RT exercises

Since 2001, 61 articles have investigated the relationship between RPE and RT in healthy subjects (Table 3). The patient ages, types of exercise, load intensities of exercise, numbers of repetitions and sets, types of RPE scale used, and main results of the included studies are described below.

Age—The majority of studies included healthy 20–30-year-old subjects. Some studies investigated healthy middle-aged and elderly subjects(1, 13, 17, 27, 42, 62, 67, 77), and a few included healthy children(63–65).

Types of exercise—Many studies used resistance exercises such as knee extension, chest press, and elbow flexion. Some studies used exercises such as back extension(13), back squats(28, 72, 81), grip force(43), and shoulder abduction(15, 62, 77).

Load intensity of exercise using 1RM or maximum voluntary contraction (MVC)—Many studies used % 1RM to investigate the relationship between RPE and load intensity during RT. RPE was correlated with % 1RM (55). Using Borg CR-10, RPE 2 was approximately 20% of 1RM and RPE 7 was indicative of 70% of 1RM for RT (55). Similarly, using the Borg 15-point RPE scale, RPE 9 correlated with 40% of 1RM and RPE 15 correlated with 80% of 1RM for RT (67). In addition, some studies often used a percentage of MVC(1, 31, 53, 58–60, 62, 77). MVC represents the maximum contraction in a specific isometric exercise as determined using electromyography. A few articles used 10RM(17, 33, 80) and 15RM(15) to investigate the relationship between RPE and the load intensity of RT. The 10RM is a weight that can be lifted 10 times, but not 11 times. Similarly, the 15RM is a weight that can be lifted 15times, but not 16 times.

Load intensity of exercise using RPE—Some research articles used RPE as the sole measure of intensity(11, 27, 34, 35, 43, 53, 55, 76). In these studies, subjects produced muscular force corresponding to RPE.

Numbers of repetitions and sets of exercise—Many studies included several repetitions and 1–3 sets of exercise during RT. Some studies used voluntary isometric contractions (the maximum contraction force as determined by the individual subject)(1, 34, 43, 53, 56, 59, 60, 62).

Types of RPE scale used—Most studies used the Borg CR-10 to investigate the relationship between RPE and the load intensity of RT. The Borg 15-point RPE scale and OMNI-RES were also used in some studies.

Main results—RPE increased with the load intensity of exercise during RT, the number of repetitions of exercise performed, the number of sets performed, and the duration of exercise. Additionally, the reported RPE scale score increased in relation to increases in the number of repetitions of exercise, the intensity in terms of % 1RM and %MVC, as well as isometric torque.

DISCUSSION

From this review of the literature, it appears that RPE is related to the load intensity of exercise in young adults. This issue has not been studied as intensely in children and older adults, and further research is therefore needed. This review revealed that many types of exercise have been assessed, with the upper and lower extremities being used more often than the neck and trunk muscles. Future research should aim to correct this imbalance and investigate the neck and trunk muscles in more detail.

Increasing the load intensity in terms of % 1RM leads to corresponding increases in RPE during RT. However, it has proven difficult to confirm a reliable agreement between % 1RM and RPE. It is not clear if 50% of 1RM represents an RPE of 5 in all subjects(9). We believe that the overall findings suggest a relationship between RPE and increased load intensity of exercise, but consistent agreement between % 1RM and RPE is still difficult to determine.

RT is frequently used as a component of rehabilitation programs for patients with various diseases, such as osteoarthritis(51), heart failure(29), chronic obstructive pulmonary disease(12, 78), stroke(48), and cancer(19, 30), and more. The findings of this review suggest that RPE is probably appropriate for determining the optimal load intensity of exercise during RT in order to ensure maximal rehabilitative benefit.

Future research

As the studies discussed in this review involved healthy subjects, future studies should aim to investigate the utility of RPE in patients with a variety of diseases. It should be expected that patients with certain diseases would report higher RPE scores than healthy subjects for the same RT tasks. Understanding how the relationship between RPE and the load intensity of exercise varies in certain disease states could produce significant benefits to the rehabilitation of these patients.

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Figure 1.
OMNI perceived exertion scale for resistance exercise

Table 1

Borg 15-point RPE scale

Rating	Descriptor
6	No Exertion at all
7	Extremely Light
8	
9	Very light
10	
11	Light
12	
13	Somewhat Hard
14	
15	Hard (Heavy)
16	
17	Very Hard
18	
19	Extremely Hard
20	Maximal Exertion

Abbreviations: RPE = Rating of perceived exertion.

Table 2

Borg CR-10 scale

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

Abbreviations: CR-10 = Category-Ratio 10.

Table 3

Study for the relationship RPE and RT

Author	Year	No. of Patients	Sex	Age	Type of Exercise	Load Intensity of Exercise	Repetitions and Sets	Type of RPE	Main Results
Allman, et al.(1)	2003	6 young adults, 6 old adults	Men	Young adults: 25; Old adults: 84	Elbow flexion	60% of MVC	Duration of voluntary isometric contractions	CR-10	RPE increased with muscle contraction time
An, et al.(2)	2015	40	Men and Women	21	Chest press, seated leg curls, leg raise, donkey calf raises, lat pulldown, and leg press.	70% of 1RM	As many repetitions as possible/1 set	Borg 6-20 RPE scale	RPE increased with the number of repetitions and EMG activity
Aniceto, et al.(3)	2015	10	Men	21.3	Bench press, 45° leg press, seated row, leg curl, triceps pulley, leg extension, biceps curl, and adductor chair.	60% of 1RM	10 repetitions/3 sets	OMNI	RPE increased during circuit weight training and multiple-set sessions
Buckley, et al.(10)	2011	40	Men and Women	19–38	Elbow extension and knee extension.	10, 20, 30, 40, 50, 60, 70, 80, 90, and 100% of 1RM	2 repetitions/1 set	CR-10	RPE increased with exercise intensity
Buckley, et al.(10)	2011	16	Men and Women	19–38	Elbow extension and knee extension.	CR rating 1.5, 3, 5	12 repetitions/1 set	CR-10	Subjects produced muscle force corresponding to levels of the RPE scale. The number of repetitions of exercise increased with RPE.
Champagne, et al.(13)	2009	16 elderly and 20 young	Men	Young adults: 22.8; Old adults: 72.8	Back extension.	Body weight only	Longest duration of isometric contraction as possible/1 set	CR-10	RPE increased with exercise duration
Colado, et al.(14)	2014	20	Men and Women	22	Lateral and front raises.	15RM	15 repetitions/1 set	OMNI	The RPE of the active muscle was greater than

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									the RPE of the entire body during exercise
Colado, et al. (15)	2012	20	Men and Women	21	Front and lateral raises,	Low and high-intensity	15 repetitions/1 set	OMNI	RPE increased with exercise intensity
Costa, et al.(16)	2015	12	Men	24	leg extension.	50% of 1RM	As many repetitions as possible/3 sets	CR-10	RPE increased with the number of sets
da Silva, et al.(17)	2007	12	Women	62.6	Bench press	10RM	10 repetitions/3 sets	OMNI	RPE increased with the number of sets
Day, et al.(18)	2004	19	Men and Women	23.4	Back squat, bench press, overhead press, biceps curl, and triceps.	50, 70, and 90% of 1RM	15 repetitions at 30% of 1RM, 10 repetitions at 50% of 1RM, 4–5 repetitions at 90% of 1RM (1 set each)	CR-10	RPE increased with exercise intensity
Duncan, et al.(20)	2006	20	Men and Women	22.2	Leg extension	30, 60, and 90% of 1RM	1 repetition/1 set	OMNI	RPE increased with exercise intensity
Elkangedy, et al.(21)	2016	12	Men	35.8	Chest press, leg press, seated rows, knee extension, overhead press, biceps curl, and triceps pushdowns.	55% of 1RM	10 repetitions/3 sets	OMNI	The mean RPE for all exercises was 5–7
Eston, et al.(22)	2009	20	Men and Women	20.8	Bilateral biceps curl and bilateral knee extension.	20, 40, and 60% of 1RM	1 repetition/1 set	Borg 6-20 RPE scale	RPE increased with exercise intensity
Farah, et al.(23)	2012	19	Men	23.9	Bench press, knee extension, seated row, knee curl, and front raise.	50% of 1RM	12, 9, and 6 repetitions/3 sets	OMNI	RPE increased with the number of sets
Focht, et al.(24)	2007	19	Women	20.6	Leg extension, chest press, torso-arm pull down, and overhead press.	75% of 1RM or a self selected intensity level	10 repetitions/3 sets	Borg 6-20 RPE scale	RPE increased with the number of sets. Self-

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									selected intensity RPE was lower than that at 75% of 1RM.
Gearhart, et al.(27)	2008	49	Men and Women	64	Leg press, lat pulldown, chest press, leg extension, leg curl, arm extension, and arm curl.	RPE 4, 6, and 8	1 repetition/1 set	OMNI	Subjects produced muscle force corresponding to load at RPE 4, 6, and 8. Exercise intensity increased with RPE score.
Gearhart, et al.(25)	2001	20	Men and Women	22.5	Bench press, leg press, lat pulldown, triceps press, biceps curl, shoulder press, and calf raise.	90% or 30% of 1RM	5 repetitions/1 set at 90% of 1RM, 15 repetitions/1 set at 90% of 1RM	Borg 6-20 RPE scale	RPE at 30% of 1RM was lower than that at 90% of 1RM
Gearhart, et al.(26)	2002	20	Men and Women	22.5	Bench press, leg press, lat pulldown, triceps press, biceps curl, shoulder press, and calf raise.	90% or 30% of 1RM	5 repetitions/1 set at 90% of 1RM, 15 repetitions/1 set at 90% of 1RM	Borg 6-20 RPE scale	RPE at 30% of 1RM was lower than that at 90% of 1RM
Gomes, et al.(28)	2015	14	Men	24	Back squat	60 and 90% of 1RM	3 repetitions/1 set	CR-10	RPE at 90% of 1RM was greater than that at 60% of 1RM
Heuser, et al.(31)	2010	20	Men and Women	19	Knee flexion	50% of %MVC	Number of repetitions to the point of failure	CR-10	RPE increased with exercise duration
Hollander, et al.(33)	2008	7	Men	25.7	Lat pull, leg press, bench press, leg extension, military press, and leg curl.	65% of 10RM	10 repetitions/4 sets	OMNI	RPE increased with the number of sets
Hollander, et al.(32)	2003	8	Men	18-30	Bench press, leg extension, military press, and leg curl.	80% of 1RM	12 repetitions/4 sets	CR-10	RPE increased with the number of sets

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John, et al.(34)	2009	15 young adults, 15 old adults	Men and Women	Young adults: 29.3; old adults: 70.8	Elbow flexion	RPE 1, 3, 5, 7, and 9	Voluntary isometric contractions	CR-10	Subjects produced isometric torque corresponding to the effort levels of the RPE scale. Isometric torque increased in relation to RPE
Lagally, et al.(36)	2009	20	Women	21.3	Chest press and knee extension.	50, 69, and 88% of 1RM for chest press, and 56, 74, and 90% of 1RM for knee extension	1 repetition/1 set	OMNI	RPE 3, 6, and 9 were related to 50, 69, and 88% of 1RM during chest press. RPE 3, 6, and 9 were related to 56, 74, and 90% of 1RM during knee extension. Subjects selection resistance load.
Lagally, et al.(40)	2002	20	Women	25	Biceps curl	30, 60, and 90% of 1RM	12 repetitions at 30% of 1RM, 6 repetitions at 60% of 1RM, 4 repetitions at 90% of 1RM (1 set each)	Borg 6-20 RPE scale	RPE increased with exercise intensity
Lagally, et al.(37)	2004	30	Men	21	Leg extension	40, 50, 60, 70, 80, and 90% of 1RM	1 repetition/1 set	Borg 6-20 RPE scale	RPE increased with exercise intensity
Lagally, et al.(39)	2006	40	Men and Women	22	Knee extension	40, 50, 60, 70, 80, and 90% of 1RM	1 repetition/1 set	OMNI, Borg 6-20 RPE scale	Both OMNI and Borg 6-20 scale increased with exercise intensity
Lagally, et al.(38)	2004	28	Women	21.7	Bench press	60 and 80% of 1RM	8 repetitions/1 set at 60% of 1RM, 15 repetitions/6 sets at 80% of 1RM	CR-10	RPE at 60% of 1RM was lower than that at 80% of 1RM

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Lagally, et al.(35)	2007	38	Men and Women	22	Knee extension	RPE 9, 13, and 17	1 repetition/1 set	Borg 6-20 RPE scale	Subjects produced muscle force corresponding to RPE. Exercise intensity during weightlifting increased with RPE.
Laur, et al.(41)	2003	32	Men and Women	25.3	Knee flexion	60% of 1RM	As many repetitions as possible/1 set	CR-10	RPE increased with the number of repetitions
Lazzarini, et al.(42)	2016	20	Men and Women	74	Chest press	5–30% (in 5% increments) of 1RM from 110% of 1RM	2 repetitions/1 set	Borg 6-20 RPE scale	RPE significantly predicted the % 1RM of chest press
Li, et al.(43)	2011	20	Men	22.1	Grip force	RPE 2, 5, 7, and 10	Voluntary isometric contractions	CR-10	Subjects produced isometric grip force corresponding to RPE. RPE increased with grip force
Lins-Filho, et al. (44)	2012	14	Men	22.9	Bench press, bent-over row, front raises, arm curl, and overhead triceps extension.	50 and 70% of 1RM	12, 9, and 6 repetitions/3 sets	OMNI	RPE was higher at 70% of 1RM than that at 50% of 1RM. RPE increased with the number of sets
McGuigan, et al.(46)	2004	17	Men and WoMen	21	Squat and bench press.	30 and 75% of 1RM	10 repetitions at 75% of 1RM, 10 repetitions at 30% of 1RM	CR-10	RPE increased with exercise intensity
Murphy, et al.(49)	2014	10 children and 10 adults	Men	Children: 9.7; adults: 25.7	Knee extension	> 80% of 1RM, 60% of 1RM	7 repetitions at > 80% of 1RM/3 sets, 17 repetitions at 60% of 1RM/3 sets	Children's Efforts Rating Table similar OMNI	RPE increased with the number of sets among both children

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									and adults. Children had higher RPE scores than adults during resistance exercise.
Naclerio, et al.(50)	2011	18	Men	22.1	Bench press	30–40, 40–50, 50–60, 60–70, 70–80, 80–90, and 90% of 1RM	3 repetitions/2 sets	OMNI	RPE increased with exercise intensity
Pincivero, et al.(55)	2003	30	Men and Women	24	Knee extension	20, 30, 40, 50, 60, 70, 80, and 90% of 1RM	2 repetitions/1 set	CR-10	RPE increased with intensity. RPE was not significantly different between men and women
Pincivero, et al.(57)	2001	30	Men and Women	26.5	Knee extension	10, 20, 30, 40, 50, 60, 70, 80, and 90% of %MVC	3–5 repetitions/1 set	CR-10	RPE increased with exercise intensity
Pincivero, et al.(56)	2002	30	Men and Women	24	Knee extension	RPE 1, 2, 3, 4, 5, 6, 7, 8, and 9	5-s maximal voluntary isometric contractions	CR-10	Subjects produced muscle contractions corresponding to RPE. %MVC increased with RPE
Pincivero, et al.(62)	2010	27	Men and Women	Young adults: 23.2; middle adults: 58.6	Shoulder abduction	10, 20, 30, 40, 50, 60, 70, 80, and 90% of MVC	10-s voluntary isometric contractions	CR-10	RPE increased with exercise intensity
Pincivero, et al.(59)	2000	30	Men and Women	24	Knee extension	10, 20, 30, 40, 50, 60, 70, 80, and 90% of MVC	5-s voluntary isometric contractions	CR-10	RPE increased with exercise intensity
Pincivero, et al.(60)	2000	17	Men	22.6	Knee extension	80% of MVC	Duration of voluntary isometric contractions	CR-10	RPE increased with muscle contraction duration

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Pincivero, et al.(52)	2011	17 young adults, 15 old adults	Unknown	Young adults: 21.7; old adults: 75.5	Knee extension	10, 20, 30, 40, 50, 60, 70, 80, and 90% of %MVC	6-s isometric contraction	CR-10	RPE increased with exercise intensity in both groups
Pincivero, et al.(52)	2011	17 young adults, 15 old adults	Unknown	Young adults: 21.7; old adults: 75.5	Knee extension	RPE 1, 3, 5, 7, and 9	6-s isometric contraction	CR-10	Subjects produced muscle contractions corresponding to the RPE scale. %MVC increased with RPE.
Pincivero, et al.(61)	2010	30	Men and WoMen	23	Elbow flexion	10, 20, 30, 40, 50, 60, 70, 80, and 90% of %MVC	5 repetitions/1 set	CR-10	RPE increased with exercise intensity
Pincivero, et al.(54)	2004	30	Men and Women	24	Knee extension	50% of 1RM	As many repetitions as possible/1 set	CR-10	RPE increased with the number of repetitions
Robertson, et al.(66)	2003	40	Men and Women	21	Biceps curl and knee extension.	65% of 1RM	4, 8, and 12 repetitions/3 sets	OMNI	RPE increased with the number of repetitions
Robertson, et al.(65)	2005	50	Men and Women	12	Biceps curl and knee extension.	50% of 1RM	14, 10, and 6 repetitions/3 sets	OMNI	RPE increased with the number of sets
Robertson, et al.(64)	2009	100	Men and Women	12.5	Biceps curl and knee extension.	30, 50, and 70% of 1RM	10 repetitions/3 sets	OMNI	RPE increased with exercise intensity
Robertson, et al.(63)	2008	70	Men and Women	11.9	Biceps curl and knee extension.	30 and 50% of 1RM	10 repetitions/2 sets	OMNI	RPE increased with the number of sets
Row, et al.(67)	2012	21	Men and Women	76.6	Leg press	34.9, 44, 52.1, 63, 73.9, 83.3, and 92.7% of 1RM	4-5 repetitions/1 set	Borg 6-20 RPE scale	RPE increased with exercise intensity

Author	Year	No. of Patients	Sex	Age	Type of Exercise	Load Intensity of Exercise	Repetitions and Sets	Type of RPE	Main Results
Shaner, et al.(69)	2014	25	Men	25	Back squat and leg press.	80% of 1RM	10 repetitions/6 sets	CR-10	RPE following exercise was significantly higher than baseline RPE
Shimano, et al.(70)	2006	16	Men	25.5	Back squat, bench press, and arm curl.	60, 80, and 90% of 1RM	As many repetitions as possible/1 set at 60, 80, and 90% of 1RM	CR-10	RPE at 60% of 1RM was higher than that at 80% and 90% of 1RM during back squat. RPE was not different between the other conditions
Singh, et al.(71)	2007	15	Men	26.7	Bench press, squats, bench pull, shoulder press, and leg extension.	50, 70, and 90% of 1RM	5 repetitions/3 sets at 50% of 1RM, 10 repetitions/3 sets at 70% of 1RM, 5 repetitions/3 sets at 90% of 1RM	CR-10	RPE at 50% of 1RM was lower than that at 70% and 90% of 1RM. Session RPE decreased over time
Spreuwenberg, et al.(72)	2006	9	Men	24	Back squat	85% of 1RM	As many repetitions as possible/4 sets	CR-10	RPE increased with the number of sets
Sweet, et al.(74)	2004	20	Men and Women	24	Bench press, lat pulldown, leg press, biceps curl, and triceps extension.	50, 70, and 90% of 1RM	6 repetitions/2 sets at 50% of 1RM, 10 repetitions/2 sets at 70% of 1RM, 4 repetitions/2 sets at 90% of 1RM	CR-10	RPE increased with exercise intensity
Testa, et al.(75)	2012	80	Men and Women	22.1	Bench press	60-80% of 1RM or 80-100% of 1RM	5.5-17.5 repetitions at 60-80% of 1RM or 1.3-2.9 repetitions at 80-100% of 1RM	CR-10	RPE increased with the maximum number of repetitions at 60-80% of 1RM or 80-100% of 1RM
Tiggemann, et al.(76)	2010	30	Men	24.6	Bench press and leg press.	RPE 11, 13, 15, and 8	12 repetitions/3 sets	Borg 6-20 RPE scale	Subjects produced

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									muscle force corresponding to RPE. Exercise intensity at % 1RM of increased with RPE
Timmons, et al.(77)	2009	12	Men and Women	23.8	Shoulder abduction	10, 20, 30, 40, 50, 60, 70, 80, and 90% of MVC	10-s voluntary isometric contractions	CR-10	RPE increased with exercise intensity
Vianna, et al.(79)	2011	17	Men	26.6	Bench press, half squat, lat pull down, and triceps extension.	12, 16, 20, and 24% of 2RM	1 repetition/1 set	OMNI	RPE increased with exercise intensity. RPE was related to energy cost during exercise
Woods, et al.(80)	2004	30	Men and Women	24.6	Knee extension	70% of 10RM	10 repetitions/3 sets	CR-10	RPE increased with the number of repetitions and sets
Zourdos, et al.(81)	2016	21	Men and Women	24	Back squat	30, 60, 90, and 100% of 1RM	1 repetition/1 set	CR-10	RPE increased with exercise intensity

Abbreviations: No = Number, RPE = Rating of perceived exertion; MVC = maximum voluntary contraction; CR = category ratio; RM = repetition maximum; EMG = electromyography