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# Accuracy and Concurrent Validity of a 5-Point Rating of Perceived Exertion Scale for Selecting and Managing Moderate Level Resistance Training Intensity

*Original Research*

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## Abstract

**Introduction**: This investigation examined the prediction accuracy and concurrent validity of the Perceived Effort Continuum (PEC) RPE scale for use with two upper body resistance training machines.

**Methods:** Twenty resistance trained participants (M = 14; F = 6) performed one exercise each on the seated row (SR) and chest press (CP) machines to obtain RPE estimation data and surface electromyographic recordings (sEMG). Each exercise was initiated with the lightest possible weight selections (WS) and terminated when the incrementally increased WS elicited a participant report of RPE 5.

**Results**: Strong positive relationships existed between RPE and sEMG for the SR ($r = .658$, $p < .001$), RPE and sEMG for the CP ($r = .615$, $p < .001$), RPE and WS for the SR ($r = .880$, $p < .001$), and RPE and WS for the CP ($r = .779$, $p < .001$). The mean WS for RPE levels 1-4 were 12%, 27%, 50%, and 80% and 17%, 31%, 51%, and 80% when normalized to a percentage of the WS of RPE 5 for the CP and SR respectively.

**Conclusions**: The PEC scale is a valid method of assessing perceived exertion during RT performed on a CP and SR and can be used to estimate a moderate level of intensity without subjecting the participant to inadvisable direct maximal testing.

***Key Words***: Functional limitations, resistance training machines, 50% 1-RM.

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## Introduction

The positive effects of regular exercise on health are well documented [1]. Exercise, regardless of the mode, can serve as a complementary intervention that can improve the health-related quality of life of patients with chronic disease or functional limitations [2]. Resistance training (RT), specifically, can reverse muscle loss, improve basal metabolism,

reduce body fat, increase physical function and performance, and increase strength [3]. RT has been demonstrated safe and effective in many chronic disease contexts [2,4-10]. Although exercise is recommended in a majority of chronic disease contexts [11], the evidence suggests that the relationship between exercise dosage and health benefits are reflected by either a U-shaped or a J-shaped curve [12]. Therefore, the selection of a moderate level of dosage is an effective choice for RT in many chronic disease contexts. Furthermore, the ability to select and manage a moderate level of RT dosage in a nuanced and individualized manner enhances safety, effectiveness, and adherence [2].

General dosage recommendations in RT are regularly described in terms of intensity and frequency. Currently, there is no single agreed upon criterion that best represents RT intensity [13]. Percentage of 1-repetition maximum (% 1-RM) [14], 5-repetition maximum [15], 10-repetition maximum [16], repetitions in reserve [17], and ratings of perceived exertion (RPE) [18] have all been used to represent RT intensity with some degree of efficacy. The most common criterion used for participants with chronic disease or functional limitations is a range based on a target % 1-RM [2,19]. However, performing a direct 1-repetition maximum (1-RM) test to determine a target % 1-RM is not recommended for many participants primarily due to safety concerns and the time constraints required to perform the procedure [20,21]. Safer indirect testing methods have been designed to predict 1-RM based on the number of repetitions one can perform until failure [22-24]. Nonetheless, because a 4-6 repetition maximum and 7-10 repetition maximum protocol require a maximum intensity effort on the last repetition, neither test would be indicated for a participant with chronic disease or functional limitations, especially those for whom it is best not to exceed a moderate level of intensity [2,19]. Therefore, many participants would benefit from a safe and effective method to determine moderate ranges of intensity while limiting exposure to the risks associated with maximal testing.

In many cases, the subjective perception of exertion is used as an alternative to direct or indirect 1-RM testing to determine intensity [2]. The Borg RPE scale was originally designed to correlate linear increases in RPE with linear increases in heart rate during aerobic exercise [26]. Due to the limitations associated with applying this scale to RT, Robertson et al. [28] designed the OMNI Resistance Exercise Scale (OMNI-RES). The OMNI-RES is characterized by having 10 levels of exertion and includes pictograph representations for each level. The most widely used RPE scales in RT are the original Borg 15-category scale [27,29] , Borg's Category-Ratio scale (CR-10) [30], and Robertson's OMNI-RES scale [18,28,32]. Most of these RPE scales consist of 10 or more rating levels. At least two RPE scales have been developed which use a coarse, 5-point rating system: The Resistance Intensity Scale for Exercise (RISE) validated for use with elastic resistance bands [33,34] and the Perceived Effort Continuum (PEC) scale developed for use in an RT feasibility pilot study for patients with persistent symptoms of Lyme disease [6]. The PEC scale was constructed as a 1-5 category RPE scale with ratio properties specific for use in a low to moderate level intensity RT intervention [6]. The investigators posited that a coarse Likert-like scale with a clearly delineated midpoint (RPE-3) might provide an intuitive framework for participants to efficiently identify and verbally communicate their momentary and predicted level of exertion between repetitions. For safety reasons, the scale was designed for the participant to predict their level of exertion for a subsequent repetition based on their experience of the preceding repetition. The PEC scale enabled the exercise trainer to terminate the set at the predetermined threshold of RPE-3 ("Moderate Effort - I can complete another repetition with some strain.") to ensure safety. Because the duration of the perceptual event (11 seconds) and the reporting phase (2 seconds) were relatively short, D'Adamo et al. [6] considered that the coarse RPE design would make it easier for a participant to discern a perceptual feeling change associated with RPE levels at the low to moderate end of the effort continuum. The difference between ratings of perceptual feelings is inherently more subtle with RPE scales that use a larger number of categories (15 for Borg, 10 for OMNI, 10 for CR-10) and may be more difficult to discern. The original PEC scale [6] used green (RPE-1), yellow (RPE-2), and red (RPE-3,4,5) color pictographs to represent the various RPE levels due to the ubiquitous association of these colors with traffic lights. The PEC scale was applied to control the intensity in all five RT exercises that were performed in the protocol. Three of the five exercises (chest press, seated row, and leg press) were performed on RT machines, and two of the exercises were performed with body weight (standing heel raise and abdominal crunch). Each exercise was performed in such a way as to allow for the participant to be unloaded during the 2 second reporting phase.

Surface electromyography (sEMG) measurement can be used to test the validity of RPE scales by providing insight into feedforward neuromotor commands that determine the sense of effort during dynamic motor tasks [27]. Previous investigators have shown that increases in muscle activation, when measured by sEMG, correlate with increases in the sense of effort [35,36]. It has been suggested that when there is a demand for greater firing rate or motor recruitment, an increase in commands from the motor cortex for greater muscle activation simultaneously generate an increase in the number of corollary signals sent to the sensory cortex and result in an increase in the sense of effort [35,37]. During RT, RPE has been shown to increase concurrently with sEMG [27] and weight selections (WS) [20]. In the context of RPE

scales, concurrent validity is established by determining how accurately the scale reflects perceived exertion throughout the entire range as exercise intensity is increased from low to high levels [20]. A primary aim of this study was to test the concurrent validity of the PEC scale by determining the strength of the relationships between RPE levels, sEMG values, and WS. Another aim of this study was to compare mean WS and reported RPE collected during the performance of individual repetitions on two upper body RT machines, the chest press (CP) and the seated row (SR), whereby RPE 1 represents a low exercise stimulus, RPE 3 represents the midpoint on the scale (50% 1-RM) and RPE 5 represents the maximal exercise stimulus (1-RM) in alignment with the Borg range model [26]. It was hypothesized that the mean weight selection of RPE 1 would represent 10%, RPE 2 would represent 25%, RPE 3 would represent 50%, and RPE 4 would represent 75% of the weight selection of RPE 5 (1-RM).

**Scientific Methods**

*Participants*

A convenience sample of twenty individuals participated in this investigation. The participants were between the ages of 25 and 80 years, included six women (M = 64.5, SD = 15.40) and 14 men (M = 49.50, SD = 16.44), and consisted of personal training clients and exercise professionals in the Oklahoma City, OK and Baltimore, MD areas who consistently participated in resistance training at least three times per week over the previous six months. The study was conducted at the fitness facility where the participants either trained or worked. All participants in this study were volunteers without limitations to exercise testing and all had previous experience with maximal voluntary isometric contraction (MVIC) testing. The participants were instructed not to have exercised for 24 hours prior to the session. Each participant wore a loose-fitting shirt, pants, and exercise shoes. Risks and benefits of the investigation were explained, and subjects provided their written consent to participate. The experimental protocol was approved by the university Institutional Review Board (IRB).

*Protocol*

All participants were supervised by the primary investigator in both locations using an identical testing and exercise protocol. The investigation used a cross-sectional, perceptual estimation design and consisted of one 1.5 hour session divided into the sEMG normalization phase, the familiarization phase, and the RT phase. All phases were conducted on the same day to maintain consistency in all procedural aspects such as placement of sEMG probes. On arrival to the fitness center, the procedures for the assessment of sEMG and the performance of the RT exercises were explained. Next was the administration of a Physical Activity Readiness Questionnaire and a written informed consent agreement. Descriptive information for each participant was obtained, including age, height, and weight.

During the normalization phase, the participants were familiarized with the MVIC testing that would be used to collect the sEMG activity unilaterally for posterior deltoid (PD) using the arm of the participant's choice and bilaterally for the pectoralis major clavicular (PM) [38]. The MVICs for the PD were performed on the same SR machine used for the estimation procedure. For the PD MVICs, the participant's arm was secured with an ankle cuff in a position of shoulder extension 10 degrees beyond zero to align with the technical principles associated with the dynamic RT exercise [33]. The PM MVICs were measured in a seated position with a device (Figure 1) constructed to mimic the palm press MVIC [38].

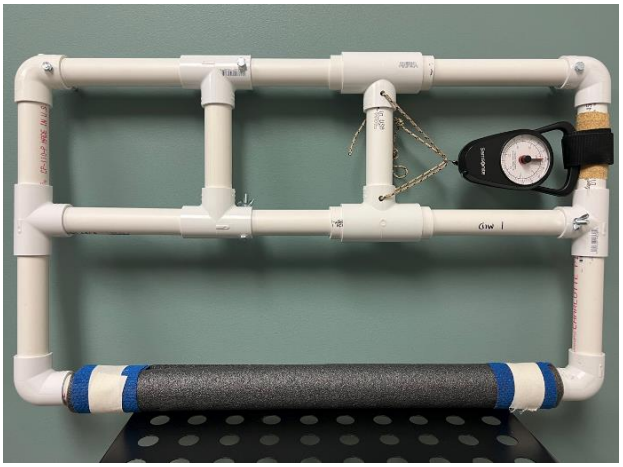

**Figure 1**: Device for participants to perform the palm press MVIC for the pectoralis major clavicular

Each MVIC was performed for 5 seconds total with a progressive increase in force for 1 second, a continuous maximum force for 3 seconds, and a gradual reduction in force over the final second. The three MVICs were performed with a rest interval of 60 seconds between each [37].

*Familiarization Phase*

The participants were familiarized with the exercise tempo and the use of the PEC scale (Figure 2). All participants were instructed that each repetition consisted of four distinct steps: Step 1 consisted of a 5 second concentric lifting stroke; Step 2 consisted of a 1 second isometric hold; Step 3 consisted of a 5 second eccentric lowering stroke; and Step 4 was a rest interval of either 30 seconds (RPE levels 1 and 2), 60 seconds (RPE level 3), or 90 seconds (RPE level 4) during which the participant was informed to report their RPE level on the PEC scale immediately after having unloaded the resistance completely.

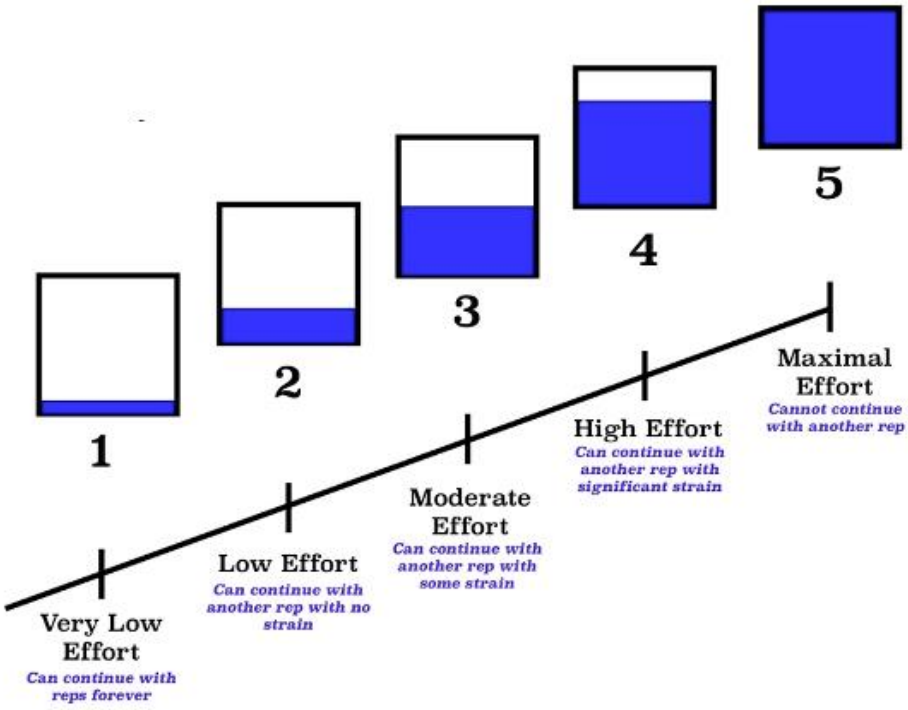


**Figure 2**: Perceived Effort Continuum (PEC) scale modified from D'Adamo et al.[6].

An exercise-specific active range of motion (ROM) assessment [39] was performed for each participant on both the SR and the CP machine. This assessment enabled the investigator to assess the ROM for each individual that was safe for each exercise eliminating the potential risk associated with resistance applied beyond an active ROM limit. The exercise specific active ROM also allowed for the adjustment of each RT machine to permit the unloading of the weight between repetitions at the end of the eccentric lowering stroke.

The following procedures were explained to each participant on how to use the PEC scale: The RPE scale you see before you has numbers from 1 to 5 and will assess the perceptions of overall body exertion you predict you would feel if you performed another repetition. This prediction is based on the perceptions of exertion that you felt during the repetition you will have just completed. The perception of physical exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during the exercise. The numbers on the scale represent a range of these feelings. The rating of RPE 1 corresponds to the idea that when thinking about the last repetition, you predict you "can continue with repetitions forever." The rating of RPE 5 corresponds with the idea that when thinking about the last repetition you predict that you "cannot complete another repetition." When the exertion level feels like you could continue to perform repetitions in perpetuity, respond with the number 1. As an example, you should

respond with the number 1 if you were performing the exercise with the lightest weight selected and it would require "no effort at all," to perform another repetition. When the exertion feels like a "maximal effort" and you could not perform another repetition, respond with a number 5. When rating your overall exertion, be sure to select the number that most accurately corresponds to your total body feelings. Please use the whole numbers on the scale as there are no half values. Provide any whole number you feel is appropriate to describe the perception of exertion you predict you will feel if you were to perform another repetition.

*Resistance Training Phase*

Following the familiarization phase, two exercises were performed to obtain the RPE estimation data and sEMG recordings. The participants performed one set of a variable number of repetitions for each of the SR and CP exercises which was terminated at a report of RPE 5. Each exercise was initiated with the lightest available WS on the machine for the selectorized machines and without any added plates for the plate-loaded machines. Following each 11 second repetition, while unloaded, the participant reported their predicted RPE followed by a rest phase that varied in length depending on the RPE value reported. Following a report of RPE values of 1 and 2, a 30 second rest interval was provided. A report of RPE 3 was followed by a 60 second rest and a report of RPE 4 was followed by a 90 second rest. During the rest time between repetitions, a 5 lb (2.27 kg) increment in weight was added to the weight stack for the selectorized machines or a 5 lb (2.27 kg) increment in weight was added to each input arm of the plate-loaded machines before the subsequent repetition was performed. This procedure continued until the participant reported an RPE 5 ("cannot continue with another repetition"). All repetition times and rest intervals were guided by a metronome synchronized to the timer embedded in the sEMG capture software which was visible to the participant on a laptop screen.

*Surface Electromyographic Recording (sEMG)*

Non-invasive sEMG was recorded using the BTS-FREEEmg and BTS EMG-Analyzer software system (BTS Bioengineering, Milan, Italy). Adhesive pre-gelled surface electrodes (24 mm Kendall silver/silver chloride discs) were used with an inter-electrode distance (20 mm), electrode placement procedure, and skin preparation following the standard the SENIAM guidelines for non-invasive sEMG [40]. For the recording of muscle activation of the PD during the SR exercise, one pair of surface electrodes was placed with the medial electrode at a distance of two finger widths behind the angle of the acromion and the lateral electrode placed along a line from the acromion to the little finger [41]. For recording of the muscle activation of the PM during the CP exercise, one pair of surface electrodes was placed with the medial electrode at a distance of two finger widths below the midpoint of the clavicle and the lateral electrode placed along a line from the medial electrode to the PM muscle attachment site on the humerus [41]. All signals were acquired at a sampling frequency of 1,000 Hz per channel, amplified, and digitized. The signals were band-pass filtered with a fourth order Butterworth filter between 20 Hz and 400 Hz. The root mean square (RMS) value with a moving window of 500 ms was used to analyze and process the recorded electrical signals of each repetition. For the SR and CP, the EMG-Analyzer software was used to fence off the 5 second concentric lifting stroke of each repetition from the isometric hold and eccentric stroke by visual analysis to identify the signal's maximum amplitude value. For the MVIC collected during the normalization phase, the middle 3 seconds was fenced off for the MVIC with the highest observable amplitude in order to identify its value. To normalize the sEMG data for the concurrent validity of the scale, the maximum amplitude value recorded during the concentric lifting stroke was divided by the maximum amplitude value recorded during the MVIC.

*Statistical Analysis*

Descriptive analyses were conducted using Numbers (Apple Inc., Cupertino, CA, USA) for the WS as well as to test the hypothesis that the mean WS would equate to 10% (RPE 1), 25% (RPE 2), 50% (RPE 3), and 75% (RPE 4) of the weight selection that was reported at RPE 5. For the concurrent validation component, statistical analysis was carried out using SPSS version 29 (SPSS inc., Chicago, IL, USA). To establish concurrent validity of the PEC scale, it was expected that RPE increases concurrently with increases in WS and sEMG values [28]. A Spearman Rho correlation was applied to account for the non-parametric characteristic the data following a visual histogram inspection.

**Results**

As to the concurrent validity of the PEC scale for the SR and the CP, the Spearman Rho correlation results indicate there is a significant, strong, positive association between RPE and the PD sEMG for the SR ($r = .658$, $p < .001$) and between RPE and the PM sEMG for the CP ($r = .615$, $p < .001$). The relationship between the RPE and the WS also yielded similar findings with a significant, strong, positive association between RPE and WS for the SR ($r = .880$, $p < .001$) and a significant, strong, positive association between RPE and WS for the CP ($r = .779$, $p < .001$). A significant,

strong positive association existed between RPE and sEMG for males (r = .626, p < .001), females (r = .848, p <.001), young (<48 years) participants (r = .793, p <.001), and a significant, moderate association existed for older participants (r = .497, p <.001) for the SR. Significant, strong positive associations existed between RPE and sEMG for males (r = .639, p < .001), females (r = .537, p <.001), young participants (r = .673, p <.001), and older participants (r = .584, p <.001) for the CP.

Finally, when calculating percentages of the RPE 5 weight selection, the mean weight selection for each RPE was divided by the RPE 5 weight selection for each individual. The results for the SR indicated the following mean percentages: RPE 1 = 12%, RPE 2 = 27%, RPE 3 = 50%, and RPE 4 = 80% of RPE 5 (Figure 3). The results for the CP mean percentages were: RPE 1 = 17%, RPE 2 = 31%, RPE 3 = 51%, and RPE 4 = 80% of RPE 5 (Figure 3).

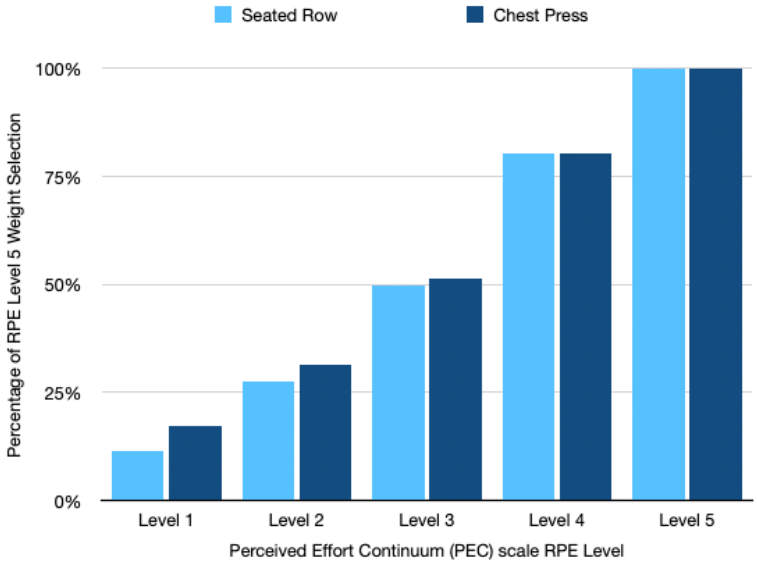


**Figure 3**: Mean weight selections (WS) represented as a percentage of the WS reported as level 5 on the PEC scale for the chest press and the seated row exercises.

**Discussion**

This study's key findings demonstrate that the PEC scale can effectively be employed to select a moderate level of intensity on two upper body resistance training (RT) machines. The PEC scale provides an alternative for determining moderate range RT intensities, especially for individuals for whom any form of maximal testing (such as 1-RM, 5-RM, 10-RM, etc.) is not recommended. Using the PEC scale, research investigators and clinicians who supervise RT programs for patients with chronic disease or functional limitations will be able to appropriately target a moderate range of intensity on a first encounter without having to perform maximal testing. Moreover, the predictive quality of the PEC scale can enable a researcher or clinician to titrate RT dosage on an individual repetition level thereby reducing the participant's risk of exposure to too high of an RT intensity. The validation of the PEC scale further supports its use in populations for whom engaging at low to moderate training intensities may be more feasible than higher levels of intensity, as previously noted with patients with persistent symptoms of Lyme disease [6].

Although the data do not entirely support the hypothesis that the mean weight selection of RPE 1-4 would correspond to 10%, 25%, 50%, and 75% of the weight selection of RPE 5, it was observed that the mean weight selection for RPE 3 was consistently 50% or 51% of the weight selection for RPE 5 in the seated row (SR) and chest press (CP) exercises respectively. This supports the fundamental idea behind the PEC scale - that level 3 represents a clear midpoint in the scale [6]. Notably, the previous study [6] terminated the exercise set when participants reported an RPE of 3 on the PEC scale, with the primary goal of maintaining the RT intensity below a moderate level for patients with persistent symptoms of Lyme disease to ensure safety and feasibility. The current study's data further endorse the utility of the PEC scale in populations where a low to moderate level of RT intensity is required. Additionally, the data revealed that

the mean weight selection for RPE 2 corresponds to 27% of the weight selection for RPE 5 in the SR and 31% of the weight selection for RPE 5 in the CP. This finding could be of significance in research settings where qualified participants lack recent exercise engagement, allowing the PEC scale to be employed to estimate a moderate level of intensity (50% 1-RM) without unnecessarily exposing participants to such intensity on the first day. This suggests the possibility of using the PEC scale to determine the mean weight selection associated with RPE 2 in the initial session and multiplying that number by a factor of 1.85 for the SR and 1.61 for the CP to estimate a 50% 1-RM level of intensity, thus eliminating the need for maximal intensity testing.

This study was limited to healthy participants engaging in RT exercises for the upper body in order to determine its concurrent validity. Future research should investigate its validity for use in populations for whom outcomes are far less predictable due to the characteristics of the disease. Therefore, future research should confirm these findings with different populations, on single joint motion upper body RT machines, and on RT machines for the lower body. Another limitation of this study was the small number of participants that made up the sample. There was no conflict of interest.

**Conclusions**

The results obtained in this study have significant implications for researchers, clinicians, personal trainers, and coaches involved in selecting and managing RT programs using upper body machines, particularly for participants with unpredictable exercise tolerance and adherence. The study confirms the PEC scale's validity as a reliable method for assessing perceived exertion during RT performed in this manner. The strong concurrent validity coefficients suggest that the PEC scale can effectively estimate a starting RT dosage level within the low to moderate range of intensity without requiring participants to undergo inadvisable direct maximal testing. Its intuitive framework allows participants to easily identify and verbally communicate their momentary and predicted exertion levels between repetitions. Notably, the PEC scale's coarse design is deemed appropriate for lower RT intensity levels, where changes in perceived exertion on finer scale constructs may be challenging to discern effectively. These findings support the practicality and reliability of using the PEC scale as a valuable tool for individuals engaging in upper body RT programs.

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