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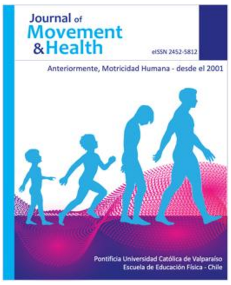

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Original article

Perceived exertion at 40%, 60%, and 80% of one-repetition maximum in intermediate-trained men during ACSM-based resistance exercise prescription

Esfuerzo percibido al 40%, 60% y 80% de una repetición máxima en hombres con entrenamiento intermedio durante la prescripción de ejercicio de resistencia basada en el ACSM

Inacio, P.A[1]; Portugal, E.M.M.[2]; Busch, D[2]; Pedon, W.R[1]; Fonseca, D.F[1]; Silva, W.A[3]; Borges, C[4]; Sá Filho, A.S[1,2,3]

Correspondence
PhD. Alberto Souza Sá Filho
Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Goiás, Brazil.
doutor.alberto@outlook.com

Abstract
Objective: To test the validity of the resistance training intensity prescription table proposed by the American College of Sports Medicine (ACSM) by comparing the rating of perceived exertion (RPE) after exercise at 40%, 60%, and 80% of one repetition maximum (1RM). **Methods:** Sixteen recreationally trained men (age: 25.1 ± 5.5 y; body mass: 84.4 ± 8.6 kg; height: 178.0 ± 6.2 cm) completed three sessions in a randomized crossover design, performing three sets of eight repetitions at a fixed speed in the exercises lat pulldown, leg extension, bench press, and leg curl, at 40%, 60%, or 80%. RPE was recorded immediately after each exercise. Single-sample t-tests compared observed RPE values with ACSM values (40% 1RM = RPE 2–3; 60% 1RM = RPE 4–5; 80% 1RM = RPE 6–7). Variations in effect sizes were calculated (ES). **Results:** All intensities produced significantly higher RPE values than those predicted by the ACSM ($p < 0.001$). The largest discrepancies were observed at 60% 1RM (ES: 1.4–2.5) and 80% 1RM (ES: 1.5–2.5). For upper limb exercises, at 40% (ES: 0.5–0.9), the RPE approached the recommendation. **Conclusion:** Under the specific conditions tested, the ACSM table may underestimate the RPE elicited by submaximal resistance exercises performed with fixed repetitions.

Key words: rate of perceived exertion; resistance training; exercise prescription

Resumen
Objetivo: Probar la validez de la tabla de prescripción de intensidad de entrenamiento de resistencia propuesta por el Colegio Americano de Medicina Deportiva (ACSM) comparando la calificación de esfuerzo percibido (RPE) después del ejercicio al 40%, 60% y 80% de una repetición máxima (1RM). **Métodos:** Dieciséis hombres entrenados recreativamente (edad: 25,1 ± 5,5 años; masa corporal: 84,4 ± 8,6 kg; altura: 178,0 ± 6,2 cm) completaron tres sesiones en un diseño cruzado aleatorizado, realizando tres series de ocho repeticiones a una velocidad fija en los ejercicios jalón al pecho, extensión de piernas, press de banca y flexión de piernas, al 40%, 60%, 80%. La RPE se registró inmediatamente después de cada ejercicio. Se compararon los valores de RPE observados con los valores de ACSM mediante pruebas t (40% 1RM = RPE 2–3; 60% 1RM = RPE 4–5; 80% 1RM = RPE 6–7). Se calcularon las variaciones en los tamaños del efecto (TE). **Resultados:** Todas las intensidades produjeron valores de RPE significativamente más altos que los predichos por el ACSM ($p < 0,001$). Las mayores discrepancias se observaron en 60% 1RM (TE: 1,4–2,5) y 80% (TE: 1,5–2,5). Para los ejercicios de extremidades superiores, en 40% (TE: 0,5–0,9), el RPE se aproximó a la recomendación. **Conclusión:** En las condiciones específicas evaluadas, la tabla del ACSM puede subestimar la RPE provocada por ejercicios de resistencia realizados con un número fijo de repeticiones.

Palabras clave: índice de esfuerzo percibido; entrenamiento de resistencia; prescripción de ejercicio

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Key points

- The ACSM %1RM–RPE table underestimated perceived exertion at 40%, 60%, and 80% of 1RM across all exercises in intermediate-trained men.
- The greatest discrepancies occurred at 60% and 80% of 1RM, with large to very large effect size.
- In this sample, 40%, 60%, and 80% of 1RM were perceived as hard, very hard, and extremely hard, respectively.

Introduction

The precise prescription of resistance training intensity is a cornerstone strategy for optimizing strength gains[1], muscle mass[2,3] and health-related outcomes[4,5]. Traditional prescription models have relied on repetition maximum zones (e.g., 8-12 RM) or a percentage of one-repetition maximum (%1RM) load corresponding to one maximum repetition (i.e. %1RM)[2,3]. Parallel to this, reflecting an evolving paradigm in training prescription, psychophysiological metrics, such as the Rating of Perceived Exertion (RPE) and the Repetitions in Reserve (RIR) concept, have gained prominence in clinical and athletic practice due to their high external validity and applicability[3] ACSM proposed a guiding table (Table 5, p. 1341) that correlates RPE descriptors (e.g., "light," "moderate," "vigorous") with specific %1RM ranges (e.g., 30-49%, 50-69%, 70-84%). The main advantages of this proposal are: i) the potential for individualizing prescription based on the individual's capacity; ii) ease of application in clinical practice due to the flexibility in choosing the prescription variable; and iii) the diversification of guiding variables for exercise professionals.

Nevertheless, the ACSM authors themselves highlight a critical limitation: "no studies have compared all of the methods of measurement of exercise intensity simultaneously; therefore, it cannot be assumed that one method of determining exercise intensity is necessarily equivalent to that derived using another method"(p. 1341)[3]. For example, Lagally et al.[6] showed an increased blood lactic, electromyography, and RPE in a dose-dependent manner with exercise intensity. This caveat points to a central gap in the concurrent validity of these recommendations. Although recent reviews, such as that by Morishita et al., have robustly established a linear, ascending relationship between RPE and external load in resistance exercise[7] these findings are often constrained to specific populations and controlled contexts, leaving applied questions unanswered[8].

Two primary gaps, identified by Morishita et al. and others[7], limit the direct extrapolation of these relationships to ACSM-based prescriptive practice: A) The Effect of Training Status: Most evidence derives from healthy young adults or elderly populations, with scarce data on individuals with intermediate or advanced resistance training experience. Studies indicate that trained and untrained individuals report different RPEs for the same absolute or relative load[9,10]. Therefore, it remains unclear how training status modulates the RPE-%1RM correlation proposed by the ACSM. B) The Influence of Proximity to Concentric Failure: The relationship between RPE and load is highly sensitive to the effort exerted during a set. Training to or near momentary muscular failure elevates RPE independently of the load. The ACSM table, however, does not specify this operational parameter, creating ambiguity regarding under which effort condition (e.g., to failure or with repetitions in reserve) its proposed equivalence is valid.

This exploratory study sought to address these two gaps (A and B) using a cross-sectional design. To investigate gap A, we recruited participants with an intermediate training status (defined by body weight-to-load lifted ratios), representative of a large segment of the gym-going population. To isolate and control for the confounding effect of gap B, we fixed the

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repetition zones for three different loads (40%, 60%, and 80% 1RM) across four common exercises, thereby preventing proximity to failure from being a free variable.

Therefore, considering the importance of subjective variables for exercise prescription[11-13], and the need to verify the practical equivalence between RPE and %1RM, the purpose of this study was to test the validity of the resistance training intensity prescription table proposed by the ACSM by comparing the RPE after exercise at 40%, 60%, and 80% of one repetition maximum (1RM). We hypothesized that the RPE values reported by intermediate-trained men during resistance exercises performed at 40%, 60%, and 80% of 1RM would differ from the RPE values expected according to the ACSM %1RM-to-RPE prescription table.

Methods

Experimental Approach

This study used a randomized crossover repeated-measures design[14]. Participants completed three experimental resistance training sessions in a randomized order, with loads corresponding to 40%, 60%, or 80% of their 1RM. The RPE values obtained were compared to the RPE ranges proposed by the ACSM. To control for the confounding effect of proximity to failure, all sessions employed a fixed repetition scheme (three sets of eight repetitions), fixed inter-set and inter-exercise rest (2 min), and a fixed movement velocity (2 s concentric, 2 s eccentric). All experimental procedures were conducted in accordance with the ethical principles for research involving human participants and were approved by the Research Ethics Committee of the Federal University of Rio de Janeiro. All participants provided written informed consent before participation.

Participants

This study included sixteen recreationally trained men participants: age = 25.1 ± 5.5 years, height = 178.0 ± 6.2 cm, weight = 84.4 ± 8.6 kg. The sample was restricted to male participants because recruitment was based on convenience and because this approach reduced sex-related heterogeneity. They should not have any injuries or illnesses and should practice strength training regularly for at least six months. Participants who presented any injury during the experiment or who used any drug that could cause alterations in physiological or performance markers were excluded. Training Level Classification: To objectively define and justify the "intermediate training level" of our sample, we applied the criteria proposed by Santos Junior et al.[15] for classifying the level of resistance training.

To objectively define the sample as intermediate, we applied the criteria proposed, which consider uninterrupted training time and strength level relative to body mass [15]. According to these criteria, all 16 participants were classified as intermediate (training time: 8.1 ± 4.3 months; bench press 1RM/body mass ratio: 1.02 ± 0.15). No participant was classified as beginner or advanced.

An a priori calculation of the sample size was performed using the G*Power software (version 3.1.9.7). For a one-sample t-test, with an effect size (d) of 0.8 (considered large), an alpha level of 0.05, and a desired statistical power of 0.80, the calculation indicated a minimum required sample size of 15 participants. A large effect size (Cohen's d = 0.8) was used, based on studies that investigated the RPE-load relationship[12-13].

Study Overview and Visit Structure

The study consisted of five visits, each separated by 48–72 h: Visit 1: Informed consent, CAD risk stratification, anthropometric assessment, body composition analysis, and familiarization with the 1RM testing procedures, exercise technique, and the CR-10 RPE scale.

DOI: https://doi.org/10.5027/jmh-Vol24-Issue1(2027)art296

Visit 2: 1RM testing for the four exercises (lat pulldown, leg extension, chest press, leg curl).
Visits 3–5: Experimental sessions performed in randomized order, with loads corresponding to 40%, 60%, or 80% of 1RM.

Morphological and Anthropometric Procedures

Anthropometric assessments were conducted during the first visit to characterize the sample. Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (WELMY 110 CH, Santa Bárbara d'Oeste, Brazil), with participants wearing light athletic clothing and no shoes. Height was measured to the nearest 0.1 cm using a fixed stadiometer (Sanny, São Paulo, Brazil). These core measurements followed standardized protocols akin to those recommended by the International Society for the Advancement of Kinanthropometry (ISAK).

To estimate body composition, body fat percentage was assessed via the skinfold technique. Skinfold thickness was measured at three sites (chest, abdomen, and thigh) following the anatomical landmarks described by Jackson and Pollock for their three-site protocol[16] All measurements were taken on the right side of the body using a scientific skinfold caliper (Cescorf, Porto Alegre, Brazil; constant pressure of 10 g/mm²). The mean of three consecutive measurements at each site was recorded and used for analysis. Body density was calculated using the corresponding Jackson and Pollock equation for men, and subsequently converted to body fat percentage using the Siri equation[17]. To ensure reliability and consistency, all anthropometric assessments were performed by the same experienced researcher.

One Repetition Maximum Testing 1RM

In the 2nd visit, the participants, now familiarized with the exercises, underwent the 1RM test for the respective exercises: lat pulldown, leg extension, bench press, and leg curl, in that order, with a 10–20-minute interval between exercises. The 1RM test is characterized by the maximum load lifted for a single repetition. Before performing the movements, participants were instructed to perform a general warm-up on a cycle ergometer for 5 minutes at a moderate intensity and self-selected load, using the RPE scale as a parameter, not exceeding a perceived exertion of moderate (RPE = 4). After the warm-up, participants performed the 1RM test, which consisted of a standard warm-up and technical adjustment in the first set, with a load equivalent to 50% of the self-reported 1RM, for a range of 8-10 repetitions, with a 1-minute rest interval; a 2nd set with an estimated 70%, for 4-6 repetitions; and finally, a last set with 90% for 1 repetition. After a 1-minute rest interval, the estimated total 1RM load was tested. If the participant was able to perform a complete movement followed by a second one, 5% of external load was added, and a 3-5 min rest interval was given, totaling a maximum of 3 attempts. If the participant was able to perform 2 subsequent movements on the third attempt, the load was recorded, and after 48 hours, another 1RM test was performed, considering the load lifted in the last session. All procedures for the test followed the ACSM[18], in order to avoid external factors and reduce errors, the following measures were taken: all participants were properly instructed on the test procedures and the execution technique for all exercises, including in the familiarization session; all tests were monitored by a trained and qualified professional in strength and conditioning; in case of execution error, the repetition was considered invalid; all tests were always performed at the same time for each respective participant, always accompanied by two or more researchers, as well as the same equipment used for the 1RM test and in subsequent visits. Participants were required to maintain their routine and eating habits, but to avoid performing any type of strength exercise 24 hours before the tests.

DOI: https://doi.org/10.5027/jmh-Vol24-Issue1(2027)art296

Category Rating of Perceived Exertion (CR-10)

For RPE analysis was used the Category Ratio Scale (CR-10)[19], was assessed at the end of each exercise. As an anchor procedure for the lowest RPE, the participants should perform 1 repetition without any weight. Thus, they were instructed to think about their perceptions of exertion of overall body and assigning a minimal RPE. The instructions for high perceptual anchor were performed during 1RM test. Perform 1RM test with a weight and think about the highest RPE[20].

Configuration of the experimental sessions

The experimental sessions were randomly set in 40%, 60%, and 80% of 1RM. The RPE, by CR-10[19], was assessed at the end of each exercise. The selected exercises were the same applied in the 1RM test for the intensities of 40, 60, and 80% of 1RM.

Body position and ranges of motion were standardized for each exercise. The pull-downs exercise was done on a machine in the seated position with the palms forward and the hands placed at the bend on the outer grip on the bar. A complete repetition involved pulling the bar from overhead until it touched the clavicle. Leg extension was performed in the seated position Universal machine with the feet parallel and shoulder width apart. Complete range of motion involved bending the knees to a 90º angle, then making a full knee extension. The chest press exercise was used an Olympic straight bar and special washers to offer resistance. The grip used was demarcated by the thumbs placed on the outside of the shoulders. It was considered complete range of motion and the bar touching the subject's chest and elbows in full extension. Leg curl was performed in the seated position Universal machine with the feet parallel, shoulder width apart, and knee in full extension. A knee bending was performed to 90º, followed by a knee extension. The concentric phase was performed at the moment of knee flexion.

The participants performed three sets with eight repetitions, which each cycle was performed in 4 s, the recovery time between exercises and sets was 2 min, resulting in a total time of 20.2 min. The execution of the movement was cadenced by a metronome (Seiko /DM-50) consisting of the period of 2 seconds per phase of the movement (concentric / eccentric). This approach of equalization was necessary to highlight the effects of exercise intensity on RPE. All settings were based on recommendations from ACSM[3]. The RPE, by CR-10[19] was assessed at the end of each exercise.

Statistical Analysis

After testing the homogeneity by Levene´s test and normality by Shapiro-Wilk test, one-sample t-tests were used to compare the observed RPE values with the ACSM-expected RPE values[18] for each exercise and intensity. Because 12 planned comparisons were performed, corresponding to four exercises across three intensities, a Bonferroni correction was applied to control the family-wise error rate, resulting in an adjusted significance threshold of $p < 0.0042$. The magnitude of differences (ES) to each exercise intensity was established by effect size analyzes and it interpreted as suggested by Hopkins[21] (trivial (<0.2), small (0.2–<0.6), moderate (0.6–<1.2), large (1.2–<2.0), very large (2.0–<4.0), and extremely large (≥4.0). Considering that, the values suggested by ACSM not contain information about dispersion, the effect size calculation considered only dispersion generated by the present study, and was calculated as described in Equation 1. The analyzes were performed with SPSS (v. 17 for Windows, USA) and the significance level was $p \leq 0.05$.

DOI: https://doi.org/10.5027/jmh-Vol24-Issue1(2027)art296

Equation 1.

$$ES = \frac{Mean_{RPE} - Expected_{RPE}}{SD_{RPE}}$$

Where: $Mean_{RPE}$ - mean of the RPE found in the present study; $Expected_{RPE}$ - RPE suggested by ACSM; SD_{RPE} - standard deviation of the RPE found in the present study.

Results

The results of the 1RM test were presented in Table 1. The RPE found in the present study compared to ACSM' recommendation resulted in significant differences in the 40% 1RM (Pull Down, $t_{15} = 6.60$, $p = 0.0001$; Leg Extension, $t_{14} = 10.21$, $p = 0.0001$; Chest Press, $t_{15} = 7.14$, $p = 0.0001$; Leg Curl, $t_{15} = 12.25$, $p = 0.0001$), 60% 1RM (Pull Down, $t_{15} = 13.00$, $p = 0.0001$; Leg Extension, $t_{15} = 17.09$, $p = 0.0001$; Chest Press, $t_{15} = 13.13$, $p = 0.0001$; Leg Curl, $t_{15} = 15.63$, $p = 0.0001$), and 80% 1RM (Pull Down, $t_{15} = 14.72$, $p = 0.0001$; Leg Extension, $t_{15} = 16.39$, $p = 0.0001$; Chest Press, $t_{15} = 19.97$, $p = 0.0001$; Leg Curl, $t_{15} = 18.11$, $p = 0.0001$). Thus, all intensities of the exercise generated RPEs above of the suggested by ACSM (Figure 1).

Table 1. Mean ± standard deviation (SD), minimum and maximum values of the workload lifted on each exercise.

	Mean		SD	Minimum	Maximum	95% CI
Pull Down	79.5	±	12.6	65.0	100	72.8 to 86.2
Leg Extension	60.6	±	12.5	45.0	85	53.9 to 67.3
Chest Press	81.6	±	17.6	52.0	122	72.2 to 91.0
Leg Curl	35.2	±	7.5	25.0	51	31.2 to 39.2

95% CI - 95% Confidence Interval.

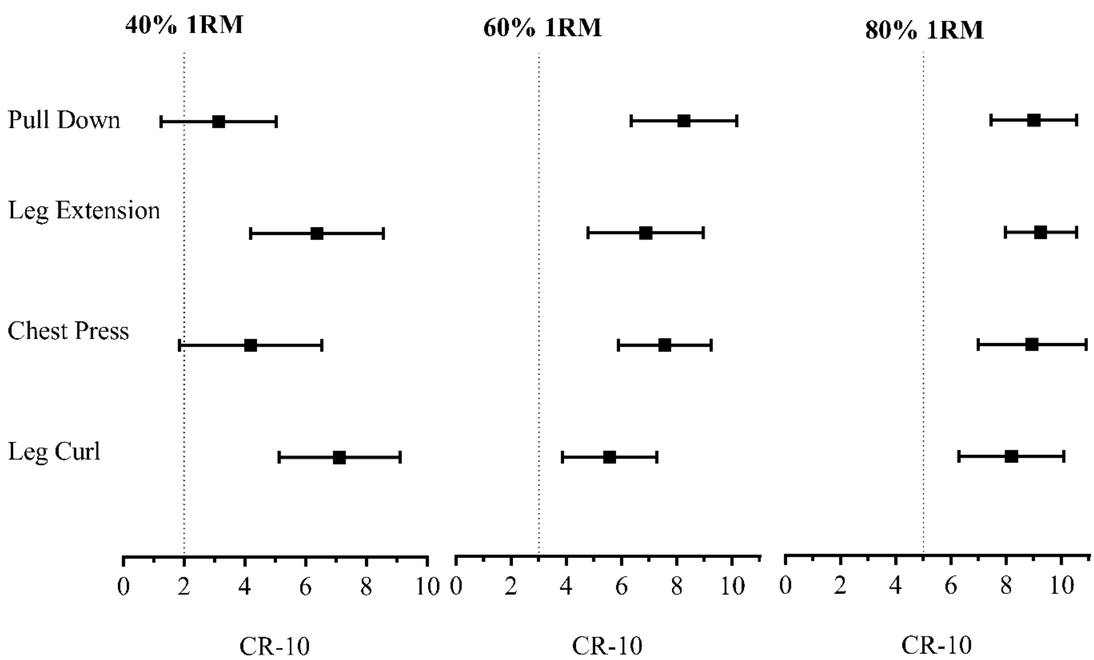

Figure 1. Mean and standard deviation of CR-10 scores to each exercise on prescribed intensities plotted against ACSM's recommendation. The dashed vertical lines indicate the expected RPE values derived from the ACSM recommendation and used for effect size calculation: RPE = 2 for 40% 1RM, RPE = 3 for 60% 1RM, and RPE = 5 for 80% 1RM. p≤.05 in all CR-10 scores compared to ACSM's recommendation.

DOI: https://doi.org/10.5027/jmh-Vol24-Issue1(2027)art296

Analyzing the ES, the largest differences were observed in 60 and 80% 1RM, because all exercises generated differences classified as large or very large. Only for upper limb exercises at 40% 1RM, the RPE approached of the ACSM' recommendation, because the difference was moderate (Table 2).

Table 2. ES and classification of CR-10 scores to each exercise on prescribed intensities compared to ACSM's recommendation.

Exercise	40% 1RM ES [95% CI]	Class	60% 1RM ES [95% CI]	Class	80% 1RM ES [95% CI]	Class
Pull Down	0.65 [0.1 to 1.18]	Moderate	1.50 [0.76 to 2.21]	Large	1.67 [0.89 to 2.43]	Large
Leg Extension	2.00 [1.10 to 2.88]	Very large	2.73 [1.64 to 3.80]	Very large	2.02 [1.14 to 2.88]	Very large
Chest Press	0.93 [0.33 to 1.51]	Moderate	1.85 [1.02 to 2.66]	Large	3.29 [2.02 to 4.55]	Very large
Leg Curl	2.57 [1.53 to 3.59]	Very large	2.74 [1.64 to 3.82]	Very large	2.58 [1.53 to 3.61]	Very large

Class: Classification according to Hopkins [21].

Discussion

The present study tested the concurrent validity of the ACSM's %1RM-to-RPE prescription table. Our main finding is that the ACSM systematically underestimates the perceived exertion experienced by intermediate-trained individuals when they perform resistance exercise with fixed repetitions, controlled velocity, and submaximal loads. Among all four exercises and three intensities, observed RPE values were significantly higher than the ACSM-predicted ranges, with effect sizes ranging from moderate to very large.

These results contrast with the original ACSM proposition[3] but are consistent with a growing body of evidence. Tiggemann et al[12,13] reported that, in strength-trained individuals, RPE-based prescriptions of "light" (CR-10 ~2–3) required loads of only 34–40% 1RM, whereas "moderate" (CR-10 ~4–5) required ~47–50% 1RM values substantially lower than the %1RM suggested by the ACSM for those same perceptual descriptors. Similarly, Lagally et al[6] observed that 60% 1RM elicited RPE values in the "light to somewhat hard" range, and 80% 1RM produced RPE values of "somewhat hard to hard," again above the ACSM's "moderate" and "vigorous" descriptors.

At first glance, the study by Day et al.[11] appears to support the ACSM table: their participants rated 70% 1RM (10 repetitions) as "somewhat hard–hard" (CR-10 ~5–6) and 90% 1RM (4–5 repetitions) as "very hard" (CR-10 ~7–8). However, direct comparison is limited by two methodological differences. First, Day et al. did not control movement velocity; slower velocities increase time under tension and elevate RPE independently of load [11]. Second, their participants performed single sets, whereas our protocol used three sets the cumulative fatigue across multiple sets may have amplified RPE responses. Thus, the discrepancy between our findings and those of Day et al. likely reflects the higher metabolic and perceptual demands of our standardized, volume-controlled design[11].

We propose three non-mutually exclusive explanations. First, the ACSM table may implicitly assume that sets are performed with substantial RIR. In our fixed-repetition protocol, eight repetitions at 60% and 80% 1RM brought participants close to concentric failure, particularly in lower-limb exercises. This proximity to failure elevates RPE independently of load [7]. Second, the table was likely developed from studies involving predominantly untrained or elderly individuals, who exhibit attenuated perceptual responses for a given relative load[8]. Our intermediate sample, by contrast, may have developed a more accurate calibration of effort. Third, the ACSM descriptors are qualitative; their translation into discrete CR-10 values is

DOI: https://doi.org/10.5027/jmh-Vol24-Issue1(2027)art296

necessarily arbitrary. We chose the midpoint of each suggested range, but it is possible that the original authors intended a more conservative interpretation (e.g., "moderate" = CR-10 3–4). Even using the most conservative boundaries, however, our observed values exceeded them.

An additional finding that deserves consideration is the exercise-specific pattern of the standardized mean differences. Although all exercises showed RPE values above the ACSM-expected values, the magnitude of this discrepancy was not uniform across exercises. The leg curl consistently showed very large effects across all three intensities, whereas the pull down showed a smaller discrepancy at 40% 1RM. This pattern may be partly explained by differences in the amount of active muscle mass, local metabolic demand, and proximity to task failure across exercises. Smaller or more isolated muscle-group exercises may induce greater local fatigue and discomfort for a given relative load, thereby increasing perceived exertion beyond what would be predicted by %1RM alone[6,7]. Previous evidence indicates that RPE during resistance exercise is associated not only with external load but also with physiological and neuromuscular markers such as blood lactate and electromyographic activity, supporting the interpretation that local fatigue contributes to perceptual responses[7]. Therefore, the ACSM %1RM-to-RPE correspondence may not be equally applicable across exercises.

Limitations

The sample comprised young, male, intermediate-trained volunteers, limiting generalization to women, older adults, beginners, or advanced athletes. We also did not include physiological correlates (e.g., blood lactate, electromyography) that could provide insight into the perceptual responses. The fixed-repetition scheme although necessary for internal validity does not reflect the full spectrum of resistance training prescription; different repetition zones or velocities might yield different RPE-%1RM relationships. We assessed global RPE only; differentiated RPE (active muscle vs. cardiovascular) might reveal distinct response patterns[6,11]. Finally, the ACSM itself does not provide numeric CR-10 equivalents for its descriptors; our operationalization, although transparent and conservative, may not perfectly represent the original authors' intent.

Conclusion

In young intermediate-trained men performing fixed-repetition, multi-set resistance exercises with controlled movement velocity, the ACSM %1RM-to-RPE table may underestimate perceived exertion under the specific conditions tested. The observed RPE values were higher than the ACSM-predicted ranges across the selected exercises and intensities, with standardized mean differences ranging from moderate to very large according to Hopkins' scale. These findings suggest that exercise professionals should use caution when applying the ACSM %1RM-to-RPE correspondence in similar training contexts, particularly when fixed repetitions and multiple sets are prescribed.

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Affiliations

[1] Graduate Program in Movement and Rehabilitation, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Goias, Brazil.
[2] Graduate Program in Physical Education, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil.
[3] Graduate Program in Pharmaceutical Sciences, Pharmacology and Therapeutics, Evangelical University of Goiás – UniEVANGÉLICA, Anápolis, Goiás, Brazil.

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[4] Department of Physical Education, University Center of Goiatuba (UniCERRADO), Goiatuba, Goiás, Brazil.

Author Contributions
PAI: conceptualization, methodology, investigation, data collection, and writing, original draft. EMMP: conceptualization, methodology, supervision, and writing, review and editing. DB, WRP, and DFF: investigation, data collection, and writing, review and editing. WAS and CB: methodology, data interpretation, supervision, and writing, review and editing. ASSF: conceptualization, formal analysis, data interpretation, supervision, project administration, and writing, review and editing. All authors read and approved the final version of the manuscript.

Conflict of Interest
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Declaration of generative AI and AI-assisted technologies in the writing process
During the preparation of this manuscript, the authors used ChatGPT (OpenAI version 5.0) only for minor grammatical corrections, language polishing, and translation support. The tool was not used to generate scientific content, formulate hypotheses, perform data analysis, interpret results, or draw conclusions. All intellectual content, analyses, interpretations, and final decisions were produced and verified by the authors, who take full responsibility for the content of the manuscript.

Data Availability
The data will be made available upon request.