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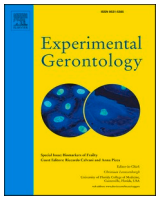

Validity of repetitions in reserve for prescribing resistance exercise in older adults

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ABSTRACT

We aimed to assess the validity of predicted repetitions in reserve (RIR) during resistance exercise (RE) in community-dwelling older adults ($n = 25$; 68 ± 4 yrs.; body mass index [BMI] = 28.1 ± 4.6 kg·m^{-2}). Prior to data collection, participants were familiarized with resistance training as well as with the use of RIR and rating of perceived exertion (RPE). Participants completed a one-repetition maximum (1RM) test in the chest press exercise. The repetitions-to-failure test, used to determine actual RIR, was then performed at 65 %-1RM. On a subsequent visit, participants performed 3 sets (65 %-1RM) at the maximum intended velocity (quantified *via* linear position transducer) until attaining 3 different predicted RIR (2, 4 and 6; in randomized order). After each set, participants reported their RPE. Velocity loss in the last repetition of the predicted RIR-2 (16 % compared to the corresponding repetition in the repetitions-to-failure test; $p < 0.001$) and RIR-4 (10 %; $p = 0.009$) was significantly greater, whereas no difference was found for RIR-6 (0 %; $p = 0.989$). Participants underestimated the number of repetitions for predicted RIR-2 (−2.1 ± 0.3 reps *vs.* actual RIR-2; $p < 0.001$) and RIR-4 (−1.6 ± 0.6 reps; $p = 0.003$), but not for RIR-6 (0.1 ± 0.8 reps; $p = 0.823$). Predicted RIR-2 was associated with greater velocity loss and number of repetitions compared to predicted RIR-4 and RIR-6 ($p < 0.05$). RPE values did not significantly differ between predicted RIR-2, RIR-4 and RIR-6 (8.0 ± 0.2, 7.6 ± 0.2, and 7.3 ± 0.3, $p > 0.05$), suggesting limited sensitivity. Our findings suggest that using predicted RIR may lack precision for accurately prescribing RE in older adults, but might be relatively useful for volume monitoring, especially when interpreted alongside RPE.

Trial registration: ClinicalTrials.gov ID: NCT05619250

1. Introduction

Aging is associated with progressive physiological and functional decline, resulting in a progressive deterioration of muscle mass and strength (Distefano and Goodpaster, 2018). This process can lead to conditions such as sarcopenia, which significantly impacts quality of life and increases the risk of disability and mortality in older adults (Evans et al., 2024). Resistance exercise (RE) has been widely recognized as one of the most effective interventions to counteract age-related declines in muscle mass and function (Cannataro et al., 2022; Fragala et al., 2019). Indeed, the World Health Organization (WHO) recommends that older adults engage in RE at least 2 days per week, emphasizing its role in maintaining functional independence (Bull et al., 2020). However, the effectiveness of RE largely depends on the prescribed exercise dose, which includes, among others, the intensity, volume, and frequency of training sessions (Borde et al., 2015).

Although precise prescription of RE is key to achieving benefits, current methods present both advantages and limitations. Objective methods—particularly those based on velocity monitoring—have gained attention for their accuracy in quantifying fatigue and

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prescribing effort, especially by controlling the magnitude of velocity loss during a set (Alcazar et al., 2021; Pareja-Blanco et al., 2020). Despite their precision, velocity-based methods require technical equipment that is often inaccessible to older populations (Kebede et al., 2022). In this context, subjective methods such as repetitions in reserve (RIR) and the OMNI-RES perceived exertion scale offer viable alternatives for prescribing RE, although they remain insufficiently validated (Gearhart Jr. et al., 2011; Helms et al., 2016). RIR is a self-regulated method where individuals estimate the number of repetitions they can still perform before reaching failure (Halperin et al., 2022). Similarly, OMNI Resistance Exercise Scale (OMNI-RES) is a validated rate of perceived exertion (RPE) scale specifically designed for RE, allowing individuals to rate their effort on a scale from 0 to 10 (Lagally and Robertson, 2006). Both methods are expected to offer a more accessible and cost-effective approach for RE prescription (Bastos et al., 2024). Furthermore, consistent with the RIR-based RPE framework, Zourdos et al. (2016) demonstrated an inverse relationship between RIR and RPE, whereby higher RPE values corresponded with progressively lower RIR estimations—thereby supporting the theoretical coherence and practical complementarity of these subjective effort methods.

Despite growing interest in the application of the RIR method within RE research (Pelland et al., 2022; Zourdos et al., 2021), recent reviews indicate that its use for quantifying proximity to failure is inconsistently reported, making it difficult to develop clear recommendations for optimizing hypertrophy and strength. In this regard, it is useful to distinguish between muscular failure—defined as the point at which no further concentric repetitions can be completed despite maximal effort—and technical failure, which refers to the point where exercise form deteriorates or compensatory strategies emerge, requiring the set to be terminated for safety and standardization (Pelland et al., 2022). Recognizing this distinction is relevant when interpreting the accuracy of subjective methods such as RIR. Zourdos et al. (2021) further investigated the difference between the 'actual RIR' and the 'predicted RIR' reported by participants. Their study revealed that participants were less accurate in predicting RIR when aiming for a perceived effort of 5 RIR or 3 RIR compared to 1 RIR during a single set to failure at 70 % of their squat one-repetition maximum (1RM). In addition, prior studies have demonstrated that individuals frequently underestimate their actual RIR when relying on subjective predictions, particularly at higher predicted RIR values (*i.e.,* farther from failure), which further underscores the inherent limitations of perceptual accuracy in non-failure conditions (Armes et al., 2020; Pelland et al., 2022). It is worth noting, however, that most RIR-based studies have focused on young healthy participants (Ruiz-Alias et al., 2024; Zourdos et al., 2016), and there are limited studies using the RIR specifically in older adults. Buskard et al. (2019) compared 4 different RE prescription methods—including RIR and RPE—in older adults over an 11-week intervention. The intervention program encompassed 8 machine-based REs (*e.g.,* seated chest press, leg curl, hip adduction, biceps curl). All prescription methods improved functional outcomes; however, participants in the RIR group achieved significantly greater training loads by the end of the program. While these findings underscore the potential utility of subjective prescription strategies in older populations, they do not address the validity or precision of RIR estimations during RE sessions. The literature on the validity of the RIR method in older adults remains scarce, especially when compared to objective measures such as intra-set velocity loss and the actual number of repetitions completed. This gap in the literature underscores the need for further research to validate subjective methods against more objective measures in this population. Therefore, the main purpose of this study was to determine whether the 'predicted RIR' is accurate to prescribe RE dose in older adults compared to the 'actual RIR'. The secondary purpose was to evaluate whether RPE values (OMNI-RES) were associated with objective indicators of effort—namely velocity loss and number of repetitions—within each predicted RIR condition. We hypothesized that the predicted RIR would underestimate the actual RIR, particularly at lower target RIRs (near-to-failure sets). Additionally, we expected a moderate-to-strong correlation between RPE and objective indicators of effort at each RIR.

2. Materials & methods

2.1. Study design

To evaluate the validity of the predicted RIR for prescribing RE in older adults, a quasi-experimental study with a within-subject design across 2 separate sessions was conducted (Fig. 1). Briefly, during the first testing session participants completed a 1RM test in the chest press exercise followed by a repetitions-to-failure test at 65 % of their established 1RM, performed until technical failure. On the second testing session, participants performed 3 sets with 65 % of 1RM, with the number of repetitions limited according to different predicted RIR. Moreover, they performed 3 repetitions at maximal intended velocity using the same relative load (65 % of 1RM) both 5 min before and 5 min after the RE session to assess neuromuscular status at baseline and post-exercise fatigue, respectively. MPV was used as the primary indicator, with the fastest repetition considered for comparison.

2.2. Participants

Written informed consent was obtained from all participants. Twenty-five older adults (68 ± 4 years; range = 63–75 years; 56 % women, body mass index = 28.1 ± 4.5 $kg \cdot m^{-2}$) volunteered to participate in this study. All participants were familiarized with the chest press exercise, as they had participated on a RE program including this exercise in their training sessions (further details regarding the 12-week RE program are available in the previously published study protocol (Gómez-Redondo et al., 2024)). Participants were eligible if they were aged between 60 and 75 years, able to walk independently, speak and read fluent Spanish, and physically capable of engaging in an exercise program. Exclusion criteria included any upper-body injury impaired their ability to perform each repetition as fast as possible; acute or terminal illness; recent major cardiac events (*e.g.,* myocardial infarction, coronary artery bypass, or angioplasty within the past year); uncontrolled medical conditions (*e.g.,* severe infections, systemic illness); neurological or psychiatric disorders (*e.g.,* Parkinson's disease, Alzheimer's, schizophrenia, major depression); significant physical disability requiring specialized care; morbid obesity (BMI >39); uncontrolled hypertension or diabetes; 3 or more falls within the past year; or current residence in institutional care settings.

Anthropometric and body composition variables were assessed during the baseline evaluation phase of the trial, and the results are presented in Supplementary Table 1. Height and body mass were measured using a calibrated stadiometer and scale (Seca 711, Hamburg, Germany) with participants barefoot and in light clothing, to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Neck circumference was measured by placing a flexible tape below the Adam's apple, while waist circumference was taken at the midpoint between the lowest rib and the iliac crest, and hip circumference at the point of maximum protrusion of the buttocks. Waist-to-hip ratio was calculated as waist circumference divided by hip circumference.

For body composition, whole-body dual-energy X-ray absorptiometry (DXA) scans (Hologic Horizon-A, Bedford, MA, USA) were performed to estimate fat mass and lean mass. From these measures, fat mass index and lean mass index were derived by dividing the respective mass components (kg) by height squared (m^2). All assessments were performed by trained personnel using standardized protocols to ensure accuracy and reproducibility of the data.

2.3. Procedures

All measurements were conducted across 2 separate sessions under

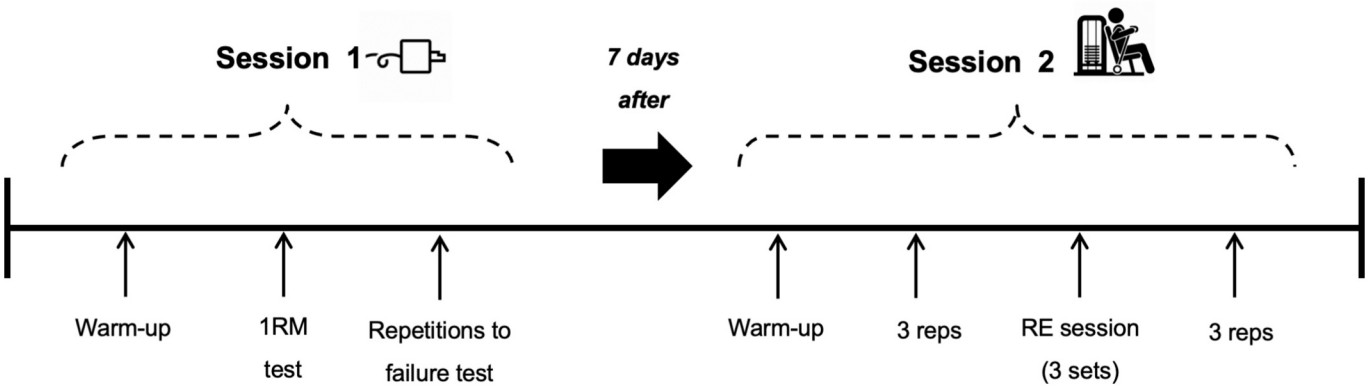

Fig. 1. Graphical summary of the study design. Abbreviation: 1RM, one repetition maximum test; RE, resistance exercise.

standardized conditions. Each testing session lasted approximately 30 to 40 min. All sessions were conducted in a gym equipped for RE testing. The setting allowed for individualized monitoring and minimized external distractions. To minimize potential bias, all evaluations were conducted by the same investigator (P.G.R), and exercise technique was carefully monitored and standardized across sessions to ensure consistent execution. To reduce inter-session variability, testing sessions were scheduled at the same time of day and on the same day of the week for each participant. Pre-assessment conditions were standardized by controlling stimulant intake (*e.g.,* caffeine), and participants were instructed to maintain their habitual routines prior to each session. A standardized warm-up of approximately 10 min was completed before each session. The warm-up consisted of 5 min of joint mobility exercises—including wrist, elbow, and shoulder circumductions, as well as scapular retractions—followed by 5 min of elastic band exercises targeting the upper body, specifically horizontal rows and chest presses. The chest press exercise was performed using a Technogym Selection machine (Technogym, Cesena, Italy). The individual setup, including the appropriate seat adjustment, was recorded for each participant to ensure consistency across testing sessions. To minimize the risk of expectancy bias in the estimation of RIR, all participants were blinded to the absolute external load used throughout all testing sessions. As such, they were unaware that the same relative load (65 % 1RM) was applied during both assessments. This blinding strategy was implemented to prevent any direct comparison or calculation based on previously performed repetitions, ensuring that subjective RIR estimations were not influenced by prior exposure to the task. A 1-s pause was imposed between the eccentric and concentric phases of the exercise to eliminate the influence of the stretch-shortening cycle (Martínez-Cava et al., 2021). The eccentric phase was performed at a controlled tempo of 2–3 s, whereas the concentric phase was executed at the participant's maximal intended velocity. To ensure the validity of the repetitions, participants were instructed to adhere to the following criteria during all testing sessions: (1) refrain from bouncing the weight plate, (2) keep the scapulae and thoracic spine in contact with the backrest, (3) maintain the pelvis and gluteal region firmly on the seat, and (4) ensure full plantar contact with the floor throughout the movement. These criteria were applied consistently to standardize performance and minimize compensatory strategies. A linear position transducer and its associated software (Chronojump Boscosystem®, Barcelona, Spain) were used to record mean propulsive velocity (MPV) during each repetition. The linear encoder was positioned on the floor adjacent to the chest press machine, and its retractable cable was securely attached to the top of the selected weight stack plate. This setup allowed for continuous measurement of vertical displacement and movement velocity during each repetition. The Chronojump system has been shown to be a valid and reliable tool for measuring movement velocity during the chest press exercise in older adults, with excellent intra-device reliability (ICC = 0.90–0.97) (Sousa et al., 2024).

2.3.1. One repetition maximum (1RM) test

The 1RM test has been shown to be a reliable method for assessing maximum strength in older adults (Barbalho et al., 2018; Grgic et al., 2020). Participants completed a 1RM test by gradually increasing the load lifted until only 1 repetition could be completed. The test began with an initial load of 5 kg for women and 10 kg for men, with subsequent increments of 5 to 10 kg applied based on individual performance. A standardized rest interval of 1 min was provided between each incremental load attempt. The 1RM was defined as the maximum load that could be lifted in a single effort with proper technique by the participant.

2.3.2. Repetitions to failure test

After completing the 1RM test, participants underwent a standardized 5-min recovery period. Subsequently, they performed a repetitions-to-failure test using a load equivalent to 65 % of their previously determined 1RM, completing as many repetitions as possible until reaching technical failure. A moderate submaximal load (65 % 1RM) was selected as it allows for assessment of RIR differences without inducing excessive fatigue and is commonly used in older adult populations (Fragala et al., 2019). Furthermore, this load has been identified as optimal for eliciting gains in muscle mass and strength within this population (Beckwée et al., 2019). The test concluded upon volitional failure or when proper exercise technique could no longer be maintained. Thus, this procedure enabled the determination of both the maximum number of repetitions participants could complete at 65 % 1RM and the actual repetitions corresponding to RIR-2, RIR-4, and RIR-6—hereafter referred to as actual RIR-2, actual RIR-4, and actual RIR-6, respectively.

2.3.3. Resistance exercise session

Participants first performed 3 repetitions at their maximal intended velocity using a load corresponding to 65 % of their 1RM, with 10-s rest intervals between repetitions. Participants then completed a 5-min rest period before performing 3 sets at a load corresponding to 65 % of their 1RM, to simulate a standard RE session. The execution order of the 3 sets (RIR-2, RIR-4, RIR-6) was individually randomized using a computer-generated sequence (random.org), without replacement and with partial counterbalancing among participants. A fixed rest interval of 3 min was applied between sets. Prior to each set, participants received standardized verbal instructions to estimate their RIR, which were phrased as follows: *"Please stop the set when you believe you could perform exactly [2/4/6] more repetitions"*. These sets were performed not as maximal efforts but as predictive trials aimed at assessing participants' ability to determine their predicted RIR-2, RIR-4, and RIR-6 values. This instruction was reiterated before each set to reinforce comprehension and standardization. Immediately after each set, researchers approached the participant with a printed OMNI-RES scale (Robertson et al., 2003) and verbally asked: *"Indicate from 0 to 10 how much effort you feel right now, where 0 is extremely easy and 10 is extremely hard"*. All participants had

previously been familiarized with both subjective methods (RIR and RPE) through a structured 12-week RE program (3 days a week; 36 sessions in total) conducted under the supervision of a sports science professional, during which they received weekly instruction and feedback to enhance the accuracy of their estimations. Following the completion of the 3 sets and a subsequent 5-min rest period, participants performed 3 additional repetitions at maximal intended velocity, with 10-s rest intervals between repetitions, to assess exercise-induced fatigue.

2.4. Statistical analyses

Data are presented as mean ± standard deviation. A paired samples *t*-test was used to analyze differences in MPV between the 3 repetitions performed immediately before and after the RE session, as an indicator of group-level fatigue. To evaluate individual-level fatigue response, the minimal detectable change (MDC) for MPV was calculated (Dontje et al., 2018) based on the same sets of 3 pre- and 3 post-RE session repetitions. To assess the accuracy of the predicted RIR values, the number of repetitions performed in each predicted RIR set (2, 4, and 6) was directly compared to the actual number of repetitions remaining at the corresponding point during the repetitions-to-failure test. For velocity loss, in the repetitions-to-failure test (session 1), the MPV at actual RIR-2, RIR-4, and RIR-6 was compared to the highest MPV recorded during that same test. In the RE session (session 2), the velocity loss was calculated by comparing the MPV of the last repetition performed in each predicted RIR set to the highest MPV recorded within that respective set. Two-way repeated measures ANOVAs (*i.e.,* condition [predicted *vs.* actual RIR], and level of RIR [2, 4, 6]) with Bonferroni's post-hoc tests were performed to explore the differences in velocity loss and number of repetitions between predicted *versus* actual RIR. In addition, Cohen's d was calculated to quantify the effect size of pairwise comparisons. Intraclass correlation coefficients (ICC) were calculated using a two-way random-effects model for absolute agreement, based on single measures. ICC values <0.5, between 0.5 and 0.75 between 0.75 and 0.9 and > 0.90 were considered indicators of poor, moderate, good, and excellent agreement, respectively (Koo and Li, 2016). Pearson's correlation coefficients (r) were calculated to examine the association between RPE values (OMNI-RES) and 2 objective indicators of effort—velocity loss (%) and number of repetitions—within each predicted RIR condition (2, 4, and 6). To assess agreement between predicted and actual RIR conditions, Bland–Altman plots were generated separately for velocity loss and number of repetitions. Differences between both conditions were plotted on the y-axis, against values from the repetitions-to-failure test on the x-axis, considered the reference standard. Mean bias and 95 % limits of agreement (±1.96 SD) were calculated. A negative bias in velocity loss indicated that greater fatigue was reached in the actual RIR condition relative to the predicted RIR sets, whereas a positive bias in repetitions indicated that fewer repetitions were performed in the predicted RIR sets compared to the actual RIR. The level of significance was set at $p \leq 0.05$. Statistical analyses were performed using IBM SPSS Statistics software (version 29.0.1.0; IBM Corp., Armonk, NY, USA).

3. Results

The average load used for the 1RM test was 34.9 ± 18.2 kg (12.5–77.5 kg), while the average number of repetitions performed in the repetitions to failure test were 13.6 ± 3.3 (8–21 reps). Determination of the 1RM required 5.0 ± 1.4 attempts. No significant differences were found between the fastest MPV recorded before and after the RE session (0.34 ± 0.06 *vs.* 0.35 ± 0.07 $m \cdot s^{-1}$, respectively; $p = 0.09$) and the mean velocity loss was 3.0 ± 9.3 %, suggesting that the 3 sets performed during the RE session did not induce fatigue. The MDC for MPV was calculated as 0.06 $m \cdot s^{-1}$; only 2 participants exceeded this threshold, and both demonstrated higher MPV in the 3 repetitions performed after the RE session compared to those performed before.

A lower velocity loss was observed during the predicted RIR 2 (Δ = 16.4 ± 1.1 %; $p < 0.001$; Cohen's d = 1.05) and RIR 4 (Δ = 10.0 ± 5.0 %; $p < 0.001$; Cohen's d = 0.57) compared to the actual RIR during the repetitions to failure test, whereas no differences were found for RIR 6 (Δ = 0.1 ± 0.0 %; $p = 0.989$; Cohen's d = 0.00) (Fig. 2**A**). Moreover, participants underestimated the number of repetitions they could perform to failure when they were asked to stop voluntarily according to their predicted RIR 2 (Δ = −2.1 ± 0.3 reps *vs.* actual RIR 2; $p < 0.001$; Cohen's d = −0.77) and RIR 4 (Δ = −1.6 ± 0.6 reps *vs.* actual RIR 4; $p = 0.003$; Cohen's d = −0.66), but not for predicted RIR 6 (Δ = 0.1 ± 0.8 reps *vs.* actual RIR 6; $p = 0.823$; Cohen's d = 0.05) **(**Fig. 2**B)**. Sex subanalysis can be found in **Supplementary Material.**

Significant differences in velocity loss were observed between predicted RIR 2 and predicted RIR 4 (Δ = −7.9 ± 0.0 %; $p = 0.009$) as well as between predicted RIR 2 and predicted RIR 6 (Δ = −9.8 ± 0.0 %; $p = 0.010$). However, no significant difference was found between predicted RIR 4 and 6 (Δ = −1.9 ± 0.0 %; $p > 0.05$). Similarly, the number of repetitions performed significantly differed between predicted RIR 2 compared to predicted RIRs 4 (Δ = 1.5 ± 0.3 reps; $p < 0.001$) and 6 (Δ = 1.8 ± 0.5 reps; $p = 0.006$), but not between predicted RIR 4 *versus* predicted RIR 6 (Δ = 0.2 ± 0.2 reps; $p > 0.05$).

A poor agreement was observed between the velocity loss observed during the actual *versus* predicted RIR for RIR 2 (ICC = −0.006; 95 %CI = −0.162, 0.229; $p = 0.523$), RIR 4 (ICC = −0.059; 95 %CI = −0.331, 0.276; $p = 0.646$) and for RIR 6 (ICC = −0.147; 95 %CI = −0.533, 0.270; $p = 0.753$). Regarding the number of repetitions, the results indicated an ICC of 0.514 (95 %CI = 0.067, 0.771; $p < 0.001$) for RIR 2, 0.588 (95 % CI = 0.182, 0.808; $p < 0.001$) for RIR 4 and 0.606 (95 %CI = 0.280, 0.806; $p < 0.001$) RIR 6. The Bland-Altman plots comparing the velocity loss and number of repetitions performed corresponding to the actual and predicted RIR 2, RIR 4 and RIR 6 are shown in Fig. 3 and Fig. 4, respectively. For velocity loss, actual RIR conditions were associated with greater decrements during the repetitions-to-failure test compared to the predicted RIR conditions performed during the RE session, as indicated by a negative mean bias (−8.8 %) and broad limits of agreement (−43.9 % to 26.3 %). The largest velocity losses were consistently observed in the RIR 2 condition, highlighting a tendency toward greater fatigue when fewer repetitions remained. Regarding the number of repetitions, participants generally completed more repetitions during the repetitions-to-failure test than during the RE session (predicted RIR sets), with a mean positive bias of +1.2 repetitions (limits of agreement:

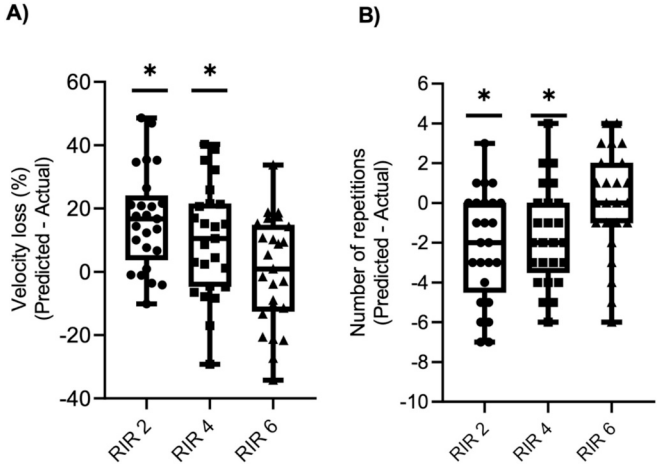

Fig. 2. Differences in velocity loss (A) and number of repetitions performed (B) between the predicted *versus* actual RIR 2, RIR 4 and RIR 6. (A) Negative numbers indicate a higher velocity loss in predicted RIR, while positive numbers indicate lower velocity loss in predicted RIR. (B) Negative numbers of repetitions indicate underestimation of predicted RIR, while positive numbers indicate overestimation. Abbreviation: RIR, repetitions in reserve. *$p < 0.01$.

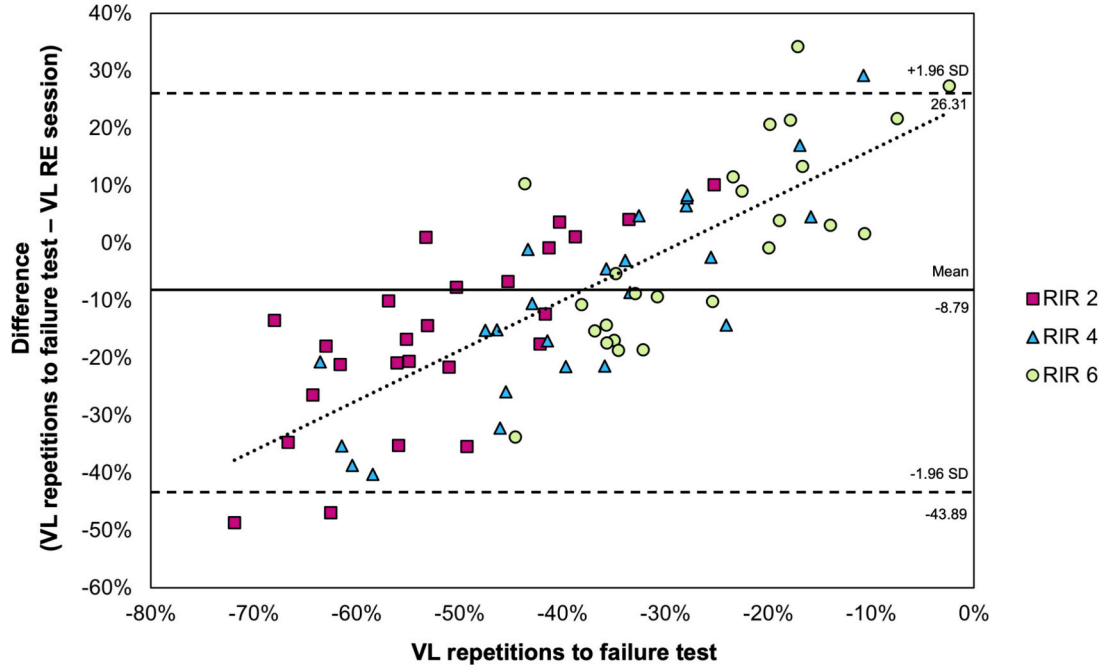

Fig. 3. Bland-Altman plot of velocity loss (%) during the repetitions to failure test for RIR 2, RIR 4 and RIR 6. Abbreviation: RIR, repetitions in reserve; RE, resistance exercise; VL, velocity loss.

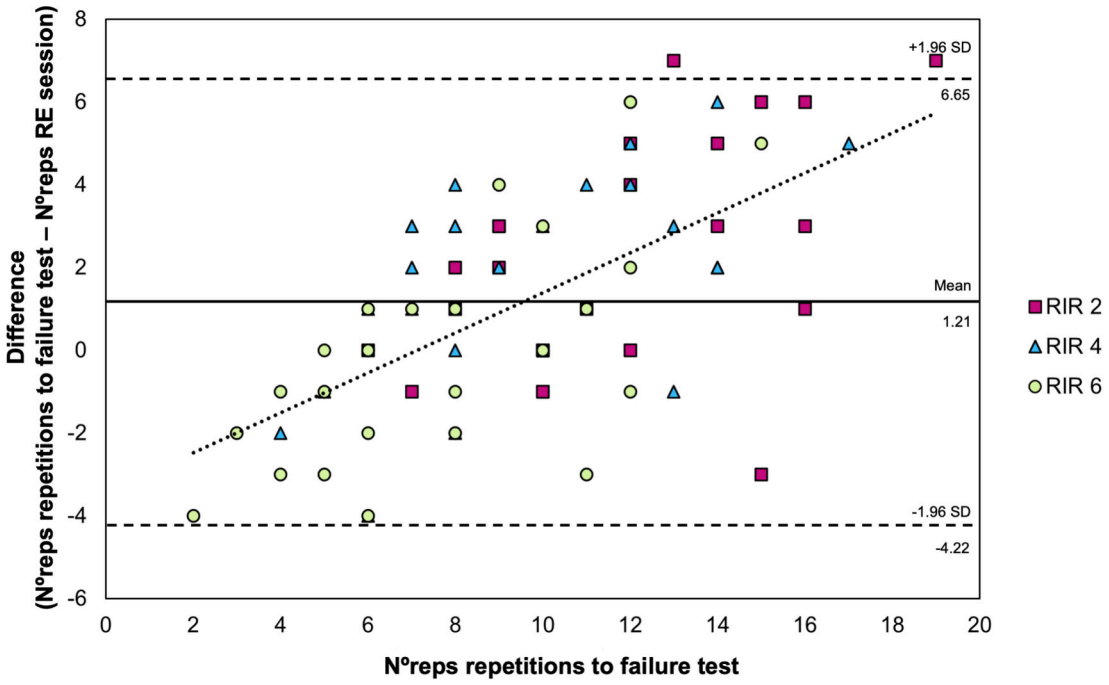

Fig. 4. Bland-Altman plot of number of repetitions during the repetitions to failure test for RIR 2, RIR 4 and RIR 6. Abbreviation: No. of reps, number of repetitions; RE, resistance exercise; RIR, repetitions in reserve.

−4.2 to +6.7). This underestimation of actual performance was most evident in lower RIR targets, particularly at RIR 2 and RIR 4.

RPE values did not significantly differ between predicted RIR 2, RIR 4, and RIR 6 during the RE session (8.0 ± 0.2, 7.6 ± 0.2, and 7.3 ± 0.3, $p > 0.05$). Fig. 5 shows the Pearson's correlation between RPE according to OMNI-RES and velocity loss/number of repetitions for predicted RIR 2, 4 and 6. No significant associations were found between these variables for any RIR condition (all $p > 0.05$).

4. Discussion

To our knowledge, this is the first study to demonstrate that older adults consistently underestimate their RIR during RE, especially at lower RIR targets. This challenges the validity of using subjective RIR for precise RE prescription in this population. This systematic underestimation may reflect age-related declines in interoception or exercise self-efficacy, which could impair accurate self-assessment of effort and fatigue. Furthermore, as a secondary aim we attempted to determine

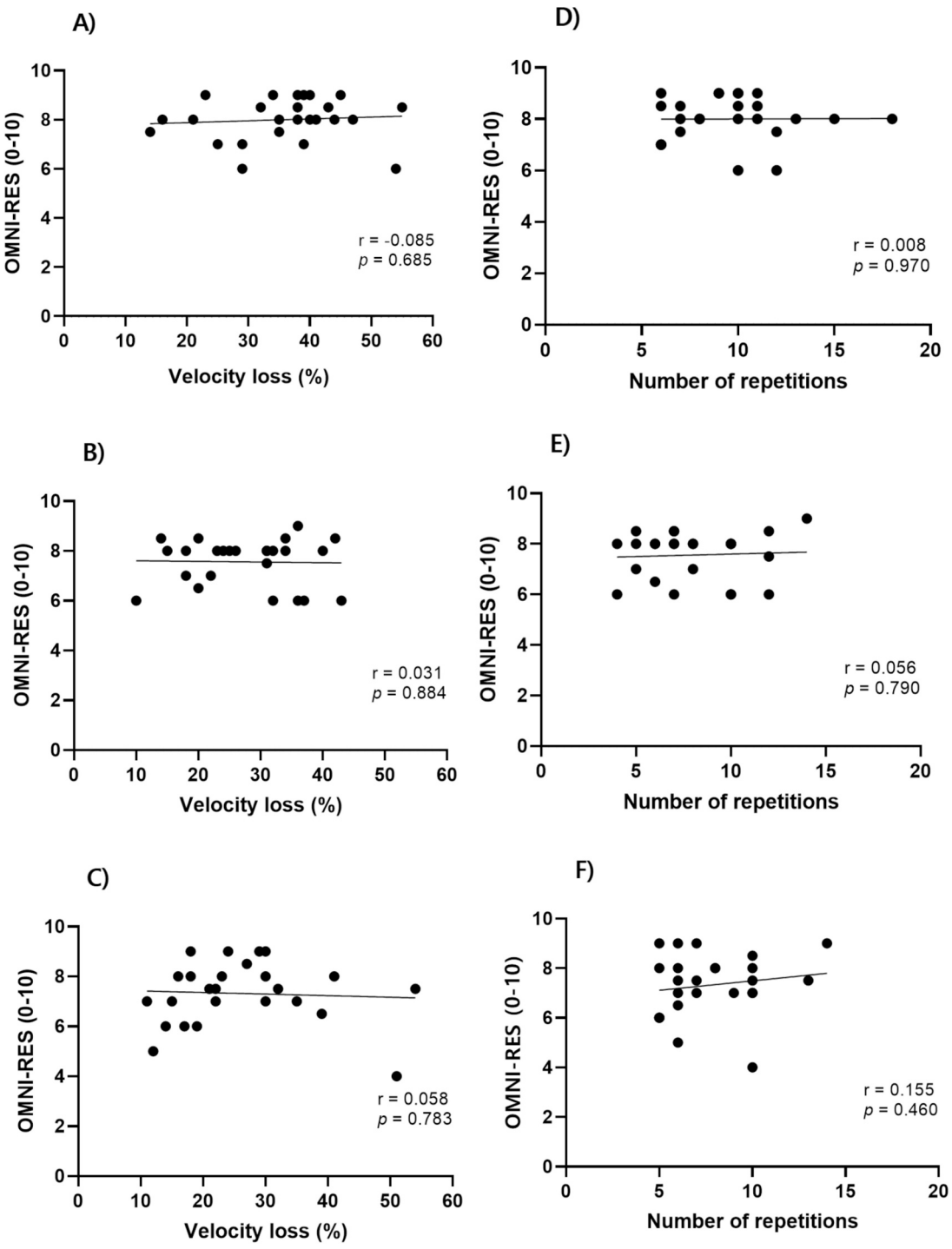

Fig. 5. Correlations between RPE according to OMNI-RES and velocity loss (%) for A) RIR 2, B) RIR 4 and C) RIR 6 and number of repetitions for D) RIR 2, E) RIR 4 and F) RIR 6. Abbreviations: OMNI-RES, OMNI resistance exercise scale; RIR, repetitions in reserve.

whether RPE values from OMNI-RES could be sensitive to different levels of RIR. We found similar RPEs across all RIR conditions, **which may reflect a limited sensitivity of the scale in this context or a reduced ability of our older participants to accurately rate their effort, potentially due to limited familiarity with self-regulation strategies or lack of training experience.** The lack of RPE sensitivity may stem from altered central processing or reduced proprioceptive acuity commonly observed in aging, which limits the ability to differentiate between effort levels. Although further research is needed to confirm the practical relevance of these findings (*e.g.,* whether the observed differences in the velocity loss and number of repetitions can eventually affect RE-induced adaptations), future studies should explore the integration of real-time feedback (*e.g.,* velocity monitoring), motor imagery training, or wearable sensors to enhance older adults' self-perception of effort and fatigue.

The validity of the RIR method has been widely debated. Previous research has shown that its subjectivity can lead to inaccuracy as individuals often underestimate their predicted RIR (Armes et al., 2020; Pelland et al., 2022). A recent meta-analysis by Halperin et al. (2022) showed an improvement in RIR accuracy when participants use heavier loads (Steele et al., 2017), in later sets (Hackett et al., 2018) or closer to failure (Hackett et al., 2017; Zourdos et al., 2021). On the same line,

Hackett et al. (2017) found that participants were more accurate in predicting RIR when performing sets closer to failure (*i.e.,* within 0–5 repetitions in reserve, particularly around 1 RIR) compared to when more repetitions remained (*i.e.,* 7–10 RIR, or more than 2 actual repetitions away from failure). Unlike prior studies in younger populations showing improved RIR accuracy closer to failure, our findings suggest that this trend does not hold in older adults, underscoring the need for age-specific approaches (Buskard et al., 2019). Contrary to findings in young participants, the present results show differences between predicted and actual RIR for RIRs 2 and 4, but not for RIR 6, which could suggest that participants more accurately estimated their RIR with lower levels of fatigue. A potential reason could be having a greater concern about injury or discomfort when they perceive a higher intensity (Little et al., 2013) resulting in older people tending to underestimate the number of repetitions they can perform until failure. Notably, although no significant differences were observed at RIR 6, agreement was poor to moderate, suggesting that the predicted RIR method may present limited accuracy even under low-fatigue conditions.

Even if the predicted RIR method may not be accurate, it remains unknown whether the observed differences could have practical implications for RE-induced adaptations. If participants consistently train at intensities below the intended dose, this may limit mechanical tension and motor unit recruitment, potentially blunting the targeted hypertrophic or neuromuscular adaptations. Although the predicted RIR overall differed from the actual RIR, lower predicted RIR values were associated with greater velocity loss and higher number of repetitions and could therefore represent a practical method to orientate training volume. This suggests that while precision in RIR estimation might be imperfect, individuals can still make considerable progress in strength and hypertrophy through RE (Refalo et al., 2024). However, whether chronic adaptations are compromised remains unclear when participants consistently fail to reach the prescribed number of repetitions. It has been shown that periodizing RE dose may not be essential to optimize neuromuscular adaptations during the initial phases of RE in older adults (Conlon et al., 2017). Instead, it may be beneficial to focus on designing exercise interventions that are perceived as more enjoyable, as this factor plays a key role in promoting long-term participation in this population (Conlon et al., 2018; Yang et al., 2024). Additional research is warranted to address these questions to better understand their implications for proper training program design.

Compared to the RIR method, RPE from the OMNI-RES has been more extensively examined in previous studies in older adults (Gearhart Jr. et al., 2009; Morishita et al., 2019). Colado et al. (2018) demonstrated that OMNI-RES is a valid method for assessing RPE during RE. However, in the present study, the RPE values reported during the RE session did not show significant variation across sets differing in RIR levels (*i.e.,* 2, 4, and 6), despite differences in velocity loss and the number of repetitions performed. This lack of differentiation may suggest difficulty among participants in accurately perceiving and reporting effort in real-time, possibly due to limited familiarization with the OMNI-RES scale or insufficient experience with self-regulation strategies. Thus, as opposed to predicted RIR values, which overall differed between different RE intensities (*i.e.,* lower RIR values associated with higher levels of fatigue, even if not accurately), RPE values failed to do so in the current application and context. Furthermore, using the OMNI-RES method may result in reaching a level of effort due to central fatigue instead of peripheral fatigue and may not achieve the desired stimulus at muscular level (Tornero-Aguilera et al., 2022). This could have important implications, as attending to the present findings, prescribing RE using the RPE values could lead to insufficient or excessive training dose, which could affect the effectiveness of the exercise intervention (Martins et al., 2015). Compared to RPE, the predicted RIR method—though imperfect—seems to align more closely with physiological markers such as velocity loss and repetitions performed. Of note, this occurred even if participants were familiarized with RE as well as with the use of both RIR and RPE methods. Throughout the 12-week training period, they routinely trained at RIR targets between 2 and 4 and reported RPE values ranging from 6 to 8. However, even among trained individuals, the accurate application of these perceptual methods remains challenging (Buskard et al., 2019). Still, this duration of exposure—especially in the absence of training to failure—may have been insufficient to establish accurate internal reference points, particularly for high-effort conditions (Greig et al., 2020). Future research should incorporate standardized anchoring protocols, test-retest reliability assessments, and repeated exposure to true muscular failure to enhance the accuracy and validity of subjective intensity estimation in older populations.

4.1. Strengths and limitations

To our knowledge, this is the first study to directly assess the validity of predicted RIR—by comparing it to actual RIR and objective measures such as velocity loss—during a RE session in older adults. However, some limitations of this research should be acknowledged. First, the results of the present study were obtained on the chest press exercise and might not be necessarily applicable to other exercises. Nevertheless, according to Gearhart Jr. et al. (2009), the results obtained using subjective methods such as OMNI-RES are consistent across both upper- and lower-body exercises. Second, assessments were conducted across 2 separate sessions; however, relevant conditions were strictly standardized to reduce potential bias. Both evaluations were scheduled at the same time of day and day of the week, and participants attended under equivalent pre-assessment conditions across sessions, including control of stimulant intake. In addition, individual exercise technique was carefully monitored and replicated between sessions, and all assessments were conducted by the same evaluator to ensure procedural consistency. Third, the sequences in which participants performed the RIRs during the training sets could have also influenced the results. To address this, condition order was randomized across participants. Another potential source of bias in studies involving subjective estimations such as RIR is the participant's awareness of prior performance, which could influence subsequent predictions. In the present study, the use of external load blinding procedures prevented participants from knowing that the same relative intensity was employed across both sessions. This methodological control reduced the risk of cognitive anchoring or performance estimation based on memory of the repetitions completed during the initial test. Additionally, participants were familiar with the chest press exercise, as it had been consistently performed during their 12-week RE program prior to the study assessments, which reduces the probability that the results were influenced by learning effects or a lack of exercise familiarity. Regarding fatigue assessment, no significant group-level differences were observed between the fastest MPV attained before and after the RE session. Importantly, prior studies in older adults have identified a 10 % velocity loss as a meaningful lower-threshold indicator of physiological adaptation to RE (Marques et al., 2022); however, none of the participants in our study reached this threshold. In addition, the MDC for the Chronojump system has been established at 0.11 $m \cdot s^{-1}$ (Courel-Ibáñez et al., 2019), and no participant in our sample exceeded this value, further supporting the absence of neuromuscular fatigue. Regarding the study population, all participants had prior RE experience, which may limit the generalizability of these findings to completely untrained older adults. Nonetheless, individual differences in learning pace, cognitive interpretation of effort, or motor awareness may still influence one's ability to self-regulate training despite their training background. Finally, regarding the methodological approach, although a 5-min rest period following the 1RM test may be suboptimal for ensuring full recovery in older adults due to the fatigue associated with maximal exertion, participants were still able to complete a relatively high number of repetitions during the subsequent repetitions-to-failure test at 65 % 1RM. The number of repetitions performed was consistent with previously reported normative values at this intensity (Graham and Cleather, 2021; Steele et al.,

2017), suggesting that any potential fatigue did not meaningfully compromise the validity of the results. On the other hand, the lack of a test-retest reliability assessment for the repetitions-to-failure test represents a methodological consideration that may affect the interpretation of our findings, as this measure served as the reference standard for evaluating RIR prediction accuracy. Future research should aim to incorporate reproducibility analyses to enhance methodological rigor.

4.2. Practical applications

Older adults seem to underestimate their RIR during RE. As a result, they may be consistently training with a lower intensity than initially intended. However, we found that velocity loss and number of repetitions were significantly greater at predicted RIR 2 compared to higher predicted RIR levels (4 and 6). Therefore, even if this method is inaccurate, the use of predicted RIR might be relatively useful to at least graduate RE dose if other methods are not available, particularly compared to the use of RPE, which seems to be even less sensitive for monitoring RE dose, as participants reported almost identical RPE values across all sets during the RE session. In line with these findings, Hackett et al. (2018) found strong to very strong correlations between actual and predicted RIR, whereas most correlations between actual RIR and RPE were small to moderate. Furthermore, it would be of interest to examine whether repeated exposure to RIR-based RE over time could improve estimation accuracy in older adults, potentially through experiential learning or feedback-based strategies.

5. Conclusions

Our findings suggest that, although lower predicted RIR values were overall associated with a larger velocity loss and a greater number of repetitions, the 'predicted RIR' method may present limited accuracy for prescribing RE in older adults. Nevertheless, it may still serve as a practical tool for guiding RE volume. RPE values derived from the OMNI-RES were even less sensitive, as there were no differences in RPE values between sets with different RIRs and velocity losses. These results underscore the challenge of relying on subjective measures for precise prescription of RE in this age group. Future studies incorporating repeated testing, anchoring procedures, and familiarization protocols may help optimize the accuracy and applicability of these subjective methods.

CRediT authorship contribution statement

Paola Gómez-Redondo: Writing – review & editing, Writing – original draft, Visualization, Project administration, Investigation, Formal analysis, Data curation. **Julian Alcazar:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Pedro L. Valenzuela:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Ignacio Ara:** Writing – review & editing, Supervision, Conceptualization. **Luis M. Alegre:** Writing – review & editing, Supervision. **Asier Mañas:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Conceptualization.

Patient consent statement

Written informed consent was obtained from all participants.

Ethics approval statement

The study was approved by the Ethics Committee for Clinical Research with Medicines of the Toledo University Hospital Complex (registration number: 881) in accordance with the Declaration of Helsinki.

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Declaration of competing interest

The authors declare no conflicts of interest related to this work.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2025.112884.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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