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Final Repetition Velocity Can Estimate Repetitions-in-Reserve in Female and Male Australian Football Athletes During Bench Press

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ABSTRACT

Objective: To evaluate the strength and reliability of the relationship between final repetition mean velocity (MV) and repetitions in reserve (RIR) during the bench press in elite female and male Australian football athletes, using a 0.5 RIR increment scale. **Methods:** 27 female and 35 male professional Australian Football athletes performed their final working set of bench press (prescribed as 4 x 6 at 80-85% 1RM) to failure with maximal concentric velocity on two separate occasions. Participants were diverse in terms of sex, experience, and strength levels. MV was measured using a linear position transducer. **Results:** A very strong MV-RIR relationship was observed (marginal $r^2 = 0.78$, conditional $r^2 = 0.86$). Athlete sex ($p = 0.409$), height ($p = 0.391$), absolute ($p = 0.379$) or relative load ($p = 0.598$), and experience level ($p = 0.691$) did not significantly influence this relationship. There was strong repeatability between sessions with no significant differences across all RIR values ($p = 0.957 – 0.255$) and low-moderate coefficient of variation (7.08 - 15.24 %). **Conclusion:** The MV-RIR relationship in professional football athletes was not affected by sex, training experience, or strength levels. Test-retest reliability was high between testing sessions. These findings provide important insights into how the velocity of the final repetition of a set can serve as an accurate estimate of proximity to failure, using a 0.5 step RIR chart. This relationship offers practitioners a valuable qualitative tool to monitor training intensity and manage proximity to failure in strength training programs.

Keywords: Velocity-based training, Strength training, Exercise prescription, Exercise monitoring.

INTRODUCTION

Velocity-based training (VBT) has emerged as a practical approach for prescribing and monitoring resistance training intensity, offering practitioners an objective method to regulate proximity to failure while accounting for day-to-day fluctuations in performance.[1] By using movement velocity as a real-time indicator of neuromuscular status,[2] VBT enables more responsive load management than traditional percentage-based prescriptions,[3,4] which is particularly relevant in team-sport environments characterised by high training volumes and variable fatigue.[5] Managing proximity to failure is important in these contexts, as training to mechanical failure can induce excessive neuromuscular fatigue,[6] compromise subsequent training quality, and increase injury risk, without necessarily providing superior strength adaptations compared with non-failure training.[7,8]

Resistance training intensity is commonly prescribed using a percentage of one-repetition maximum (1RM), based on the assumption that a predictable number of repetitions can be completed at a given relative load. However, substantial inter-individual variability exists in repetitions to failure at the same percentage of 1RM, and an athlete's capacity to express strength can fluctuate due to factors such as accumulated fatigue, readiness, and concurrent training demands.[9,10] These limitations are particularly evident in professional team-sport athletes,[11,12] where strength training is often performed alongside skill-based and conditioning sessions that can acutely impair force and velocity production.[5] As a result, there is a need for alternative strategies that allow practitioners to more accurately regulate training intensity and proximity to failure on a session-by-session basis.

The rating of perceived exertion (RPE) scale, operationalised through repetitions in reserve (RIR), has been proposed as a method to autoregulate resistance training by prescribing intensity based on how many repetitions an athlete perceives they can perform before failure.[13] Although RIR-based prescription has been shown to be valid in both novice and experienced lifters,[12,14,15] its effectiveness depends on the athlete's perceptual accuracy and the level of trust between athlete and practitioner. To address these limitations, recent research has examined the relationship between mean concentric velocity (MV) and RIR (the MV-RIR relationship), demonstrating that MV typically decreases as proximity to failure increases, following an inverse and often curvilinear pattern.[16,17] This relationship may provide a more objective indicator of proximity to failure, complementing subjective RIR-based approaches.

Several factors have been suggested to influence the MV-RIR relationship, including sex, exercise selection,[18] strength level, lifting experience,[19] and the relative load lifted.[20,21] These effects have primarily been demonstrated at lighter relative loads (e.g., 60% 1RM) compared with heavier loads (e.g., 80% 1RM).[20,21] Nevertheless, MV at differing repetitions in reserve (RIR) has been shown to remain consistent across multiple sets performed within the same session in the bench press,[21] and to be reliable between testing sessions in a separate investigation.[20] Despite growing interest in this area, most research has been conducted in recreationally trained individuals or strength-sport athletes, with limited data available in elite team-sport populations. Furthermore, although 0.5 RIR increments are commonly used in applied practice to reflect uncertainty near failure, no study has directly examined the MV-RIR relationship using a scale that incorporates these smaller increments. Examining MV across this range may therefore provide more practically relevant information for monitoring and adjusting training intensity on a set-by-set basis, particularly in elite team-sport environments where fatigue, readiness, and technical execution can vary substantially between sessions. Therefore, the primary aim of this study was to examine the strength of the relationship between final repetition MV and RIR during the bench press exercise in elite female and male Australian football athletes competing in the Australian Football League Women (AFLW) and Australian Football League (AFL). A secondary aim was to determine the within-subject reliability of the MV-RIR relationship across two testing sessions conducted within an applied training environment. It was hypothesised that a strong MV-RIR relationship would be observed, that this relationship would not be meaningfully influenced by sex, strength level, or training experience, and that MV at given RIR values would demonstrate high test–retest reliability.

METHODS

Participants

Female (AFLW; n = 27) and male (AFL; n = 35) professional Australian football players competing during the 2024 premiership season volunteered to participate in this study. All participants were free from injury at the time of data collection and had a minimum of 12 months' resistance training experience with the bench press exercise. Of the total sample, 15 female and 16 male participants completed both testing sessions, while the remaining participants completed a single testing session. Participant demographic characteristics are presented in Table 1. All participants provided written informed consent prior to participation. The study was approved by the University Human Research Ethics Committee (Approval No. 2019/359).

Experimental Design

Two experimental testing sessions were conducted at the team's high-performance facility during the AFLW and AFL pre-season periods separated by 14 days. Experimental testing was performed in the afternoon and preceded by skill and conditioning training completed 2 to 4 h prior. The skill and conditioning training were not the same within and between AFLW and AFL sessions. As such, participants presented in different states of readiness for each experimental testing session.

Table 1. Participant Characteristics.
Descriptive statistics for participants. All data are presented as mean ± standard deviation.

Metric	Female (n = 27)	Male (n = 35)
Height (cm)	173.4 ± 6.8	187.5 ± 9.3
Body Mass (kg)	73.3 ± 8.5	85.4 ± 9.3
Professional Experience (years)	3.5 ± 1.9	7.2 ± 3.8
Bench Press Ve1RM (kg)	65.5 ± 9.6	122.3 ± 12.8
3RM Bench Press (kg)	57.8 ± 8.3	110.9 ± 10.6

**Ve1RM = Velocity predicted one-repetition maximum*

Participants had a minimum of 12 months training experience in the bench press exercise. All testing sessions were supervised by a certified strength and conditioning coach accredited by the Australian Strength and Conditioning Association to ensure technical consistency and participant safety. The bench press exercise was selected as it is a commonly prescribed upper-body strength movement within Australian football strength programs.[22]

Maximal strength (velocity estimated 1RM; Ve1RM) for the bench press was assessed at the beginning of the training block as part of the teams' standard performance monitoring procedures and not specifically for the purposes of this study. All participants followed a standardised testing protocol, whereby a 3RM was achieved within two attempts and Ve1RM was later calculated using individualised load velocity profiles. The time between Ve1RM assessment and experimental testing ranged from 4 to 6 weeks.

Experimental Testing Session: Repetitions to Failure

Participants completed a prescribed resistance training session consisting of four sets of six repetitions of the barbell bench press at an intensity corresponding to 80–85% of their Ve1RM. The use of this relative intensity range reflected individualised loading strategies within the professional training program and allowed minor adjustments based on athlete readiness and training phase (females = 70.18–86.73 %, males = 73.53–91.67 %). Females averaged 5.26 repetitions (3-6) and males 5.33 (3-6).

Mean velocity was measured during the final working set using a linear position transducer (GymAware; Kinetic Performance Technologies, Canberra, Australia) attached to the barbell. Participants were instructed to perform each repetition with maximal concentric intent while maintaining controlled technique. The final set was performed to volitional mechanical failure, defined as the inability to complete a repetition through the full concentric range of motion without assistance or unacceptable technique deviations.

A repetition was deemed invalid if assistance was provided during the concentric phase or if loss of gluteal contact with the bench occurred. A spotter assisted with unracking the barbell when required. All valid repetitions were recorded; however, only repetitions corresponding to 0–5 repetitions in reserve were included in subsequent analyses.

Repetitions in reserve were retrospectively determined based on the total number of repetitions completed to failure, such that the final repetition represented 0 RIR, the penultimate repetition represented 1 RIR, and so forth. Half-point increments (0.5 RIR) were included to reflect practical uncertainty near failure, where an additional repetition may not have been confidently achievable, but additional load may have been possible. This approach aligns with applied RIR usage in resistance training practice.

Statistical Analysis

All statistical analyses were performed using R (version 4.4.1). To examine the relationship between MV and repetitions in reserve, linear mixed-effects models were constructed with MV as the dependent variable and repetitions in reserve as a fixed effect. Participant identity was included as a random intercept to account for repeated observations.

Additional models were created to assess the potential influence of sex, height, lifting experience, absolute load, and relative load (% Ve1RM) on the MV-RIR relationship. Model comparisons were conducted using Bayesian Information Criterion values to identify the most parsimonious model. As the relationship between MV and RIR was non-linear, spline regression with three degrees of freedom was applied.

Model fit was quantified using marginal and conditional coefficients of determination (r^2). Chi-square (χ^2) likelihood ratio tests were used to assess the contribution of fixed effects. Test–retest reliability was assessed using paired comparisons, Cohen's *d* effect sizes, 95% confidence intervals, coefficients of variation (CV), and Bland–Altman analysis. Effect size thresholds were interpreted as trivial (<0.2), small (0.2–0.49), moderate (0.5–0.79), and large (≥0.8). Statistical significance was set at $p < 0.05$.

RESULTS

Table 2. Relationship between mean velocity and repetitions in reserve in half point loading.
Typical movement velocity (mean velocity) per repetitions in reserve for professional female and male football athletes for the bench press. Data are presented as mean (95% confidence interval range).

Repetitions in Reserve	Velocity ($m \cdot s^{-1}$)
0	0.17 (0.16, 0.18)
0.5	0.21 (0.20, 0.22)
1	0.25 (0.24, 0.26)
1.5	0.29 (0.28, 0.30)
2	0.32 (0.31, 0.33)
2.5	0.34 (0.33, 0.35)
3	0.37 (0.36, 0.38)
3.5	0.39 (0.38, 0.40)
4	0.41 (0.40, 0.42)
4.5	0.43 (0.42, 0.44)
5	0.44 (0.43, 0.45)

The inclusion of participant-specific random effects substantially strengthened the MV-RIR model, with marginal $r^2 = 0.78$ and conditional $r^2 = 0.86$, indicating that a large proportion of variance was explained by the fixed and random effects combined. No significant effects were observed for sex ($\chi^2 = 0.68$, $p = 0.41$), height ($\chi^2 = 0.73$, $p = 0.39$), lifting experience ($\chi^2 = 0.69$, $p = 0.41$), absolute load ($\chi^2 = 0.77$, $p = 0.38$), or relative load ($\chi^2 = 0.28$, $p = 0.60$). Consequently, the final model retained repetitions in reserve as the sole fixed effect with participant identity as a random effect.

Mean velocity values for each RIR and 0.5 RIR increment are presented in Figure 1 and Table 2, which illustrates the direct, non-linear relationship between MV and proximity to failure. The shaded region and dashed bounds represent the 95 % confidence intervals. Data from female and male participants across both testing sessions are pooled, as no sex-specific differences were observed. These are further presented in Table 3.

Test–retest analyses demonstrated no significant differences in MV at any RIR value between testing sessions (p = 0.96–0.26). Mean changes in MV were trivial to small in magnitude (Cohen's d = 0.01–0.21) with confidence intervals spanning zero at all RIR values (Table 3). Bland–Altman analysis (Figure 2) demonstrated good agreement between sessions, with symmetrical dispersion of differences around the mean and no evidence of proportional bias. Coefficients of variation ranged from approximately 7.08 - 15.24 %, indicating acceptable absolute reliability within an applied training environment.

Collectively, these findings demonstrate a robust and reliable MV-RIR relationship during the bench press in elite Australian football athletes, with minimal influence from individual characteristics or loading conditions within the range examined.

DISCUSSION

The purpose of this study was to investigate the relationship between final repetition MV and repetitions in reserve during the bench press exercise in elite female and male Australian football athletes within an applied training context. The principal findings were that (i) a very strong relationship existed between MV and RIR, (ii) this relationship was not influenced by sex, strength level, height, lifting experience, or relative and absolute load lifted, and (iii) MV at given RIR values demonstrated high between-session reliability. Notably, this study is the first to characterise the MV-RIR relationship using a scale incorporating 0.5 RIR increments in a professional team-sport population.

The absence of a meaningful effect of sex, strength level, and training experience on the MV-RIR relationship aligns with several recent investigations reporting similar relationships across diverse populations when proximity to failure is low.[23-25] Although some studies suggest that individualised MV-RIR profiles may enhance precision, particularly at lighter relative loads,[19,26] other work has demonstrated that MV values at a given RIR are relatively consistent across sexes and experience levels during multi-joint exercises such as the bench press.[24] In the present study, the non-significant χ^2 values for sex, load, and experience support the interpretation that the MV-RIR relationship is robust

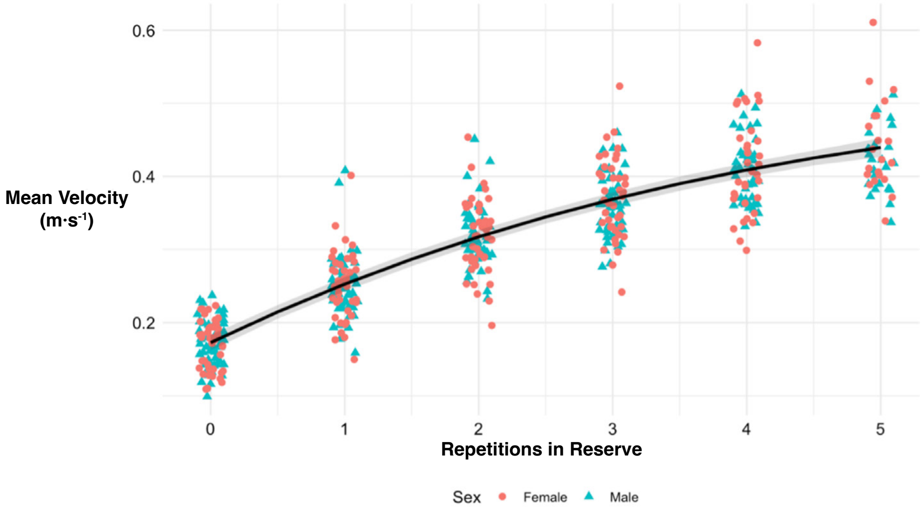

Figure 1. Relationship between repetitions in reserve and mean velocity.
Mean concentric velocity of the final repetition plotted against repetitions in reserve (RIR) during the bench press exercise in professional female and male Australian football players. Data are pooled across sexes and testing sessions. The solid line represents the fitted spline regression; the shaded region indicates the 95% confidence interval.

Table 3. Between-session mean differences and effect size-based reliability of mean velocity across repetitions in reserve.
Changes in mean velocity between testing sessions separated by 14 days for professional Australian football players. Data are presented as mean change ± SD unless otherwise stated.

RIR	Mean Velocity (m·s⁻¹)	Cohen's *d*	95% CI	*p*
0	0.002 ± 0.04	0.04	-0.01, 0.02	0.81
1	0.007 ± 0.06	0.11	-0.02, 0.03	0.56
2	0.001 ± 0.07	0.01	-0.02, 0.02	0.96
3	-0.001 ± 0.07	0.02	-0.03, 0.02	0.93
4	-0.011 ± 0.07	0.16	-0.04, 0.01	0.39
5	0.012 ± 0.06	0.21	-0.01, 0.03	0.26

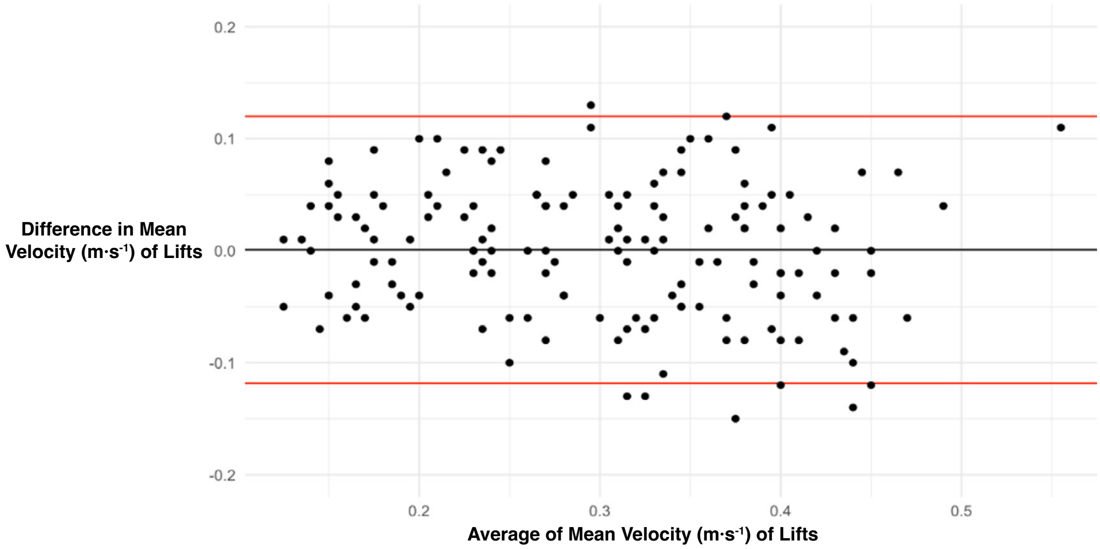

Figure 2. Bland-Altman analysis of test-retest reliability.
Bland–Altman plot illustrating agreement in mean velocity between testing sessions for pooled female and male participants. The solid horizontal line represents the mean difference between sessions, while red lines indicate the 95% limits of agreement. The absence of proportional bias and symmetrical dispersion of data indicate good test–retest reliability across the range of velocities.

in elite Australian football athletes, at least within the relative load range examined. It is important to note that the MV-RIR relationship appears to be movement-specific,[23] and its generalisability across different exercises and populations remains uncertain based on current research.[19,26]

Reliability analyses further support the practical utility of MV as an indicator of proximity to failure. Mean velocity at each RIR value showed no systematic bias between testing sessions, as evidenced by non-significant mean differences, symmetrical Bland–Altman plots, and coefficients of variation ranging from approximately 7.08 - 15.24 %. While CV values below 10 % are often considered ideal, velocity-based metrics in applied training environments commonly exhibit higher variability, particularly when data are collected during normal training sessions rather than tightly controlled laboratory conditions. Importantly, the relatively narrow confidence intervals observed in the present study suggest that MV is not a noisy measure near failure, supporting its use for monitoring purposes in elite settings.

The use of 0.5 RIR increments represents a meaningful advancement in the application of the MV-RIR relationship. In practice, athletes and practitioners frequently encounter situations in which an additional repetition cannot be confidently completed, yet additional load may still be attainable. By incorporating half-step increments, the present study provides a more nuanced representation of proximity to failure that better reflects real-world decision-making. The lack of overlap in 95 % confidence intervals up to approximately 3.5 RIR suggests that MV can meaningfully differentiate between RIR values within the range most commonly used for strength training prescription, on a re-test basis. This finding is particularly relevant given recommendations that RIR-based prescription is most appropriate up to approximately 4 RIR.

Mean velocity values observed in the present study were generally higher than those reported in recreationally trained individuals[17] and powerlifters,[27] except at 0 RIR, where MV aligned with previously reported minimal velocity thresholds for the bench press.[1] These discrepancies may reflect differences in technical execution, training background, and the applied nature of the testing environment. In professional team-sport athletes, strength exercises are typically performed to support on-field performance rather than to maximise performance in a single lift, which may influence movement strategies and velocity expression. Consequently, presenting MV values as ranges rather than fixed thresholds may be more appropriate when applying MV-RIR relationships across different populations.

From a practical perspective, the findings of this study support the use of final repetition MV as a qualitative tool for estimating proximity to failure in elite team-sport athletes. While individualised MV-RIR profiling may provide greater precision,[17,19] such approaches may be impractical in professional environments where data must be interpreted rapidly and communicated clearly. The group-based MV-RIR relationship presented here offers a pragmatic alternative that can assist practitioners in monitoring training intensity and managing neuromuscular fatigue. For example, if an athlete performs a bench press set with a final repetition speed of ~0.30 $m \cdot s^{-1}$, this corresponds to ~2 RIR according to the group MV-RIR relationship chart. A coach can then use this information to i) adjust load to reach a desired intensity, ii) adjust repetitions to reach target fatigue levels, and iii) inform athletes of their proximity to failure with objective, quantitative feedback. Moreover, real-time velocity monitoring offers autonomous feedback for both athletes and coaches, identifying repetitions where additional effort could be applied or signalling when a set is approaching mechanical failure. This approach allows for precise, data-driven adjustments that optimise training outcomes while minimising unnecessary fatigue. Nevertheless, the movement-specific nature of the MV-RIR relationship should be acknowledged,[23] and caution is warranted when extrapolating these findings to other exercises or populations. Future research should examine additional movement patterns and explore how MV-RIR relationships evolve across different phases of the training cycle.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

FUNDING

No funding was received in order for this research to be carried out.

ETHICAL APPROVAL

All participants provided written informed consent prior to participation. The study was approved by the University Human Research Ethics Committee (Approval No. 2019/359).

AUTHOR CONTRIBUTIONS

Henry Hopwood: Conceptualisation, methodology, validation, resources, data curation, writing – original draft.
Phillip Bellinger: supervision, conceptualisation, writing – review and editing.
Tim Newans: software, formal analysis, visualisation.
Clare Minahan: supervision, conceptualisation, writing – review and editing.

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