Reliability of the velocity achieved during the last repetition of sets to failure and its association with the velocity of the 1-repetition maximum

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Abstract

Background. This study aimed to determine the reliability of the velocity achieved during the last repetition of sets to failure (V_{last}) and the association of V_{last} with the velocity of the 1-repetition maximum (V_{1RM}) during the paused and touch-and-go bench press (BP) exercises performed in a Smith machine.

Methods. Ninety-six healthy men participated in this study that consisted of two testing sessions. A single BP variant (paused BP or touch-and-go BP) was evaluated on each session in a randomized order. Each session consisted of an incremental loading test until reaching the 1RM, followed by two sets of repetitions to failure against a load ranging from 75-90% of 1RM.

Results. The reliability of V_{last} was unacceptable for both BP variants (CV > 18.3%, ICC < 0.60). The correlations between V_{1RM} and V_{last} were small for the paused BP ($r = 0.18$) and moderate for the touch-and-go BP ($r = 0.37$).

Conclusions. Although these results suggest that V_{last} could be a better indicator of the minimal velocity threshold than V_{1RM}, the low reliability of V_{last} and the similar values of V_{last} for both BP variants suggest that a standard V_{1RM} should be used to estimate the 1RM from the individualized load-velocity relationship.

Keywords: bench press, linear position transducer, minimal velocity threshold, strength testing, velocity-based training.

Introduction

Movement velocity has been proposed as an accurate variable for estimating the 1-repetition maximum (1RM) during a number of resistance training exercises (García-Ramos & Jaric, 2018; McBurnie et al., 2019). Early studies proposed generalized load-velocity (L-V) relationship equations to estimate the percentage of 1RM from the velocity value recorded against a submaximal load lifted with maximal effort (González-Badillo & Sánchez-Medina, 2010). The basic premise of generalized L-V relationship equations is that a given velocity represents the same percentage of 1RM for all individuals. However, this premise has been refuted in subsequent studies which have shown a greater accuracy in the estimation of the percentage of 1RM using individualized L-V relationships (García-Ramos & Jaric, 2018; García-Ramos et al., 2018; McBurnie et al., 2019). This is also demonstrated by the between-subject variability in the velocity associated with a given percentage of 1RM being higher than the within-subject variability (Pestaña-Melero et al., 2018). On the basis of these results, an increasing number of studies have recently been conducted to refine the testing procedure of the individualized L-V relationship.

Assessment of individualized L-V relationships requires the recording of movement velocity against at least 2 submaximal loads and, subsequently, the 1RM can be estimated through a linear regression as the load associated with the velocity of the 1RM (V_{1RM} or minimal velocity threshold) (García-Ramos & Jaric, 2018; García-Ramos et al., 2018; McBurnie et al., 2019). However, one of the challenges associated with the use of individualized L-V relationships for predicting the 1RM is how to select the minimal velocity threshold. Previous studies have selected the minimal velocity threshold as either the individualized V_{1RM} (Banyard, Nosaka & Haff, 2017; Ruf, Chery & Taylor, 2018) or a general V_{1RM} for all subjects (Garcia-Ramos et al., 2019; García-Ramos et al., 2018). The assessment of the individualized V_{1RM} is associated with at least 2 problems: (I) the individual is required to perform a lift against the 1RM load, and (II) the individual V_{1RM} has been demonstrated to be an unreliable metric for a number of exercises such as the back squat (coefficient of variation [CV] = 22.5%, intraclass correlation coefficient [ICC] = 0.42) (Banyard, Nosaka & Haff, 2017), deadlift (CV = 15.7%, ICC = 0.63) (Ruf, Chery & Taylor, 2018), Smith machine bench press (BP) (CV = 13.9-15.7% , ICC = 0.54-0.64) (Pestaña-Melero et al., 2018), or bench pull (CV = 6.36%, ICC = 0.18) (García-Ramos et al., 2019). Therefore, it would be of interest to investigate whether the minimal velocity threshold (i.e. velocity value used to estimate the 1RM from the individualized L-V relationship) can be obtained with a higher reliability using other approaches that do not require the individual to perform a lift against the 1RM load.

An alternative approach for determining the minimal velocity threshold could be the assessment of the velocity of the last repetition performed during a set to failure (V_{last}) (Lake et al., 2017). This approach is supported by the results of Izquierdo et al. (2006) who did not find significant differences between the individual V_{1RM} and the V_{last} collected against 4 submaximal loads (60, 65, 70 and 75% of 1RM) during the BP and parallel back squat exercises performed in a Smith machine. A recent review has suggested that the accuracy of the individualized L-V relationship for predicting the 1RM

105 is higher for upper-body (e.g. BP or bench pull) compared to lower-body exercises (e.g.
106 squat or deadlift), while the BP is the exercise most explored in velocity-based training
107 research (McBurnie et al., 2019). The 2 main variants of the BP exercise examined in
108 the scientific literature are the paused BP (a pause is introduced between the eccentric
109 and concentric phases) and the touch-and-go BP (the concentric phase is performed
110 immediately after the eccentric phase) (García-Ramos, Pestaña-Melero, Pérez-Castilla,
111 Rojas, & Haff, 2018; Pallarés, Sánchez-Medina, Pérez, De La Cruz-Sánchez, & Mora-
112 Rodriguez, 2014; Pérez-Castilla, Comfort, McMahon, Pestaña-Melero, & García-
113 Ramos, 2018). García-Ramos et al. (2018) revealed a comparable V_{1RM} for the paused
114 BP (0.168 ± 0.026 m/s) and touch-and-go BP (0.178 ± 0.030 m/s) (P = 0.232)
115 performed in a Smith machine, while the V_{1RM} was poorly related between the BP
116 variants (r = -0.11, P = 0.554). However, no study has examined the reliability of V_{last} or
117 the association between V_{last} and V_{1RM}. Therefore, a comprehensive examination of the
118 behavior of V_{last} during the BP exercise is needed to clarify whether V_{last} may provide
119 useful information for increasing the accuracy in the estimation of the 1RM through the
120 individualized L-V relationship.
121
122   To address the aforementioned gaps in the literature, the main aim of the present
123 study was to assess the reliability of V_{last} and the association between V_{last} and V_{1RM}
124 during the paused and touch-and-go BP exercises performed in a Smith machine. In
125 addition, we aimed to determine the effect of the number of repetitions performed to
126 failure on V_{last} and the effect of 1RM strength on V_{1RM} and V_{last}. Our main hypothesis
127 was that, regardless of the BP variant, V_{last} would present a low level of reliability and it
128 would be poorly correlated with V_{1RM}. We also hypothesized that no significant
129 correlations would be observed between V_{last} and the number of repetitions performed
130 to failure, while the 1RM strength would be negatively associated with V_{1RM} and V_{last}.
131

Materials & Methods
Participants
134 Ninety-six healthy men volunteered to participate in this study (age = 20.8 ± 3.4 years
135 [range = 18-38 years]; body height = 1.73 ± 0.06 m; body mass = 75.3 ± 15.7 kg;
136 paused BP 1RM = 62.3 ± 17.6 kg; touch-and-go BP 1RM = 66.5 ± 18.4 kg; resistance
137 training experience = 1.3 ± 2.4 years [range = 0-10 years]). Eighty-six participants
138 completed both testing sessions, 7 participants only performed the paused BP, and 3
139 participants only performed the touch-and-go BP. 10 participants only performed one
140 BP variant because they reported not to be interested in attending a second testing
141 session. All participants without resistance training experience were first year sport
142 science students and they were familiarized with the BP exercise during several
143 sessions before the onset of the study. Prior to study initiation, participants were
144 informed of the study procedures and provided written informed consent. Additionally,
145 participants were instructed to avoid any strenuous exercise for the 48 hours before
146 each testing session. The study protocol adhered to the tenets of the Declaration of
147 Helsinki and was approved by the Institutional Review Board of the University of
148 Granada (491/CEIH/2018).
149
Study design

151 A randomized crossover design was used to comprehensively examine the relationship
152 between V_{1RM} and V_{last} during the BP exercise performed in a Smith machine.
153 Participants came to the laboratory on 2 occasions separated by 72-96 hours. A single
154 BP variant (paused BP or touch-and-go BP) was evaluated on each session in a
155 randomized order. Each session consisted of an incremental loading test until reaching
156 the 1RM, followed by 2 sets of repetitions to failure against a load ranging from the 75%
157 of 1RM to the 90% of 1RM. The same participant performed the 2 sets against the
158 same load for reliability purposes, while the prescribed relative load (% of 1RM) differed
159 between participants to explore the effect of the number of repetitions performed on
160 V_{last}. Participants were instructed to perform all repetitions at the maximum possible
161 velocity and the mean concentric velocity (MCV, average velocity value from the start of
162 the concentric phase until the velocity of the barbell was 0 m·s^{-1}) of the barbell was
163 recorded with a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain).
164 The 2 sessions for the same participant were held at the same time of the day (± 1
165 hour) to minimize the influence of the circadian rhythm on physical performance.
166
167 ***Procedures***
168 Both testing sessions began with a standardized warm-up which consisted of 5 minutes
169 of jogging, dynamic stretching, arm and shoulder mobilization, and 1 set of 10
170 repetitions with an external load of 20 kg (mass of the unloaded Smith machine barbell)
171 in the tested BP variant. The initial load of the incremental loading test was 20 kg and it
172 was increased in 10 kg until the MCV of the barbell was lower than 0.50 m·s^{-1}. From that
173 moment, the load was increased in increments of 1-5 kg until the 1RM load was
174 achieved. During the incremental loading test, 2 repetitions were performed when the
175 MCV was higher than 0.50 m·s^{-1}, and only 1 repetition when the MCV was lower than
176 0.50 m·s^{-1}. The rest between sets was 3 minutes when the MCV was higher than 0.50
177 m·s^{-1} and 5 minutes when the MCV was lower than 0.50 m·s^{-1}.
178
179   Ten minutes after the 1RM assessment, participants performed 2 sets of
180 repetitions to failure with a load ranging between 75% and 90% of the previously
181 determined 1RM. The 2 sets were separated by 10 minutes. Participants performed the
182 2 sets with the same load for reliability purposes, but the relative load differed between
183 participants to explore the effect of the number of repetitions performed on V_{last}.
184 Participants were instructed to perform all repetitions at the maximum possible velocity.
185 Two trained spotters were present during the test for safety reasons and to encourage
186 participants to lift the maximum possible load during the 1RM assessment and to
187 perform the maximum possible number of repetitions during the sets of repetitions to
188 failure. The BP was performed in a Smith machine (Ffittech, Taiwan, China), while a
189 linear velocity transducer, which sampled the velocity of the barbell at 1,000 Hz, was
190 used to collect the MCV of all repetitions. Note that the MCV has been reported to be
191 the most accurate velocity variable for determining the load-velocity relationship during
192 the BP exercise (García-Ramos et al., 2018c).The 2 BP variants evaluated in the
193 present study are described below:
194
195   - *Paused BP*: Participants initiated the task holding the barbell with their arms
196 fully extended. They lowered the barbell at a self-selected velocity until the barbell made

197 contact with their chest, waited with the barbell on the chest for 2 seconds, and on the
198 word 'Go!' performed a purely concentric action at maximum possible velocity until their
199 arms were fully extended.
200
201   - *Touch-and-go BP*: Participants initiated the task holding the barbell with their
202 arms fully extended. They were instructed to lower the barbell until it touched the chest
203 and then immediately perform the concentric phase at the maximum possible velocity.
204
205 ***Statistical analysis***
206 Descriptive data are presented as means and standard deviations. The normal
207 distribution of the data was confirmed by the Shapiro-Wilk test ($P > 0.05$). The reliability
208 of V_{last} was assessed through the standard error of measurement (SEM), the CV and
209 the ICC (model 3.1) with the corresponding 95% confidence interval. Acceptable
210 reliability was determined as a CV < 10% and a ICC > 0.70 (Cormack et al., 2008). The
211 association between the variables was quantified by the Pearson's correlation
212 coefficient (r) and the following scale was used to quantify the magnitude of the r
213 coefficient: trivial (.00–.09), small (.10–.29), moderate (.30–.49), large (.50–.69), very
214 large (.70–.89), nearly perfect (.90–.99) and perfect (1.00) (Hopkins, Marshall,
215 Batterham, & Hanin, 2009). Paired sample's t tests, the Cohen's d effect size (ES), and
216 Bland-Altman plots were used to compare the magnitude of the variables. The following
217 scale was used to interpret the magnitude of the ES: trivial (< 0.20), small (0.20-0.59),
218 moderate (0.60-1.19), large (1.20-1.99) and very large (≥ 2.00) (Hopkins et al., 2009).
219 The reliability assessment was performed by means of a custom spreadsheet (Hopkins,
220 2000), while all other statistical analyses were performed using the software SPSS
221 version 22.0 (SPSS, Chicago, IL, USA). Statistical significance was set at an alpha level
222 of 0.05.
223

224 Results

225 The reliability of V_{last} was unacceptable for both the paused BP (CV = 18.3%, ICC =
226 0.58) and the touch-and-go BP (CV = 20.4%, ICC = 0.48) (Table 1). The V_{1RM} was
227 significantly higher than V_{last} during the paused BP ($P = 0.028$, ES = 0.30) and the
228 touch-and-go BP ($P = 0.020$, ES = 0.29), while the magnitude of the correlations
229 between V_{1RM} and V_{last} was small for the paused BP ($r = 0.18$, $P = 0.083$) and moderate
230 for the touch-and-go BP ($r = 0.37$, $P < 0.001$) (Figure 1). No significant differences
231 between the BP variants were observed for V_{1RM} or V_{last} ($P > 0.80$), while the
232 correlations between the BP variants was trivial for V_{1RM} ($r = -0.01$, $P = 0.937$) and
233 moderate for V_{last} ($r = 0.46$, $P < 0.001$) (Figure 2). Bland-Altman plots revealed
234 comparable systematic bias (0.015-0.016 m·s⁻¹) and random errors (0.054-0.057 m·s⁻¹)
235 between V_{1RM} and V_{last} for both BP variants (Figure 3). A small and inverse relationship
236 was observed between V_{last} and the number of repetitions performed to failure (r = -
237 0.23, $P < 0.001$) and the 1RM load ($r = -0.17$, $P = 0.001$), while moderate correlations
238 were observed between V_{1RM} and the 1RM load ($r = -0.33$, $P < 0.001$) (Figure 4).
239 Participants performed the sets of repetitions to failure against an average load of 82.1
240 ± 3.7% of 1RM and completed 6.9 ± 2.3 repetitions.
241
242 **[Table 1]**

243 **[Figure 1]**
244 **[Figure 2]**
245 **[Figure 3]**
246 **[Figure 4]**
247
248 **Discussion**
249 This study is the first to investigate the reliability of V_{last} during the paused and touch-
250 and-go BP exercises, and explore the association between V_{1RM} and V_{last} within and
251 between each BP variant. Additionally, this study determined the effect of the number of
252 repetitions performed to failure on V_{last}, and the effect of 1RM strength on V_{1RM} and V_{last}.
253 The main findings of the study revealed (I) low reliability for $V_{last,}$ (II) V_{last} was
254 significantly lower than V_{1RM}, (III) no significant differences between the BP variants for
255 V_{1RM} or V_{last}, (IV) larger associations between the BP variants for V_{last} compared to
256 V_{1RM}, and (V) a negative, albeit weak, association of V_{last} with the number of repetitions
257 performed to failure and the 1RM strength. These results suggest that V_{last} could be a
258 better indicator of the minimal velocity threshold during the BP exercise than V_{1RM}
259 because V_{last} was lower than V_{1RM} and it demonstrated a stronger relationship between
260 the BP variants. However, the low reliability of V_{last}, moderate association between the
261 BP variants for V_{last}, and the lack of differences between the BP variants for the V_{1RM} or
262 V_{last} suggest that a general V_{1RM} could be more appropriate.
263
264   Previous studies have found that the magnitude of V_{last} is not affected by the load
265 applied during sets of repetitions to failure performed with the BP and back squat
266 exercises (Izquierdo et al., 2006). However, no previous study had examined the
267 reliability of V_{last} in any resistance training exercise. Our results confirmed that V_{last} is an
268 unreliable metric for the 2 variants of the BP exercise examined in the present study.
269 The reliability of V_{last} (CV = 18.3% and 20.4% for the paused and touch-and-go BP,
270 respectively) was somewhat comparable to the reliability of the MCV associated with
271 the 1RM load reported by Pestaña-Melero et al. (2018) (CV =13.9% and 15.7% for the
272 paused and touch-and-go BP, respectively). Therefore, it seems that neither the V_{1RM}
273 nor the V_{last} should be used on an individual basis since the within-subject variability of
274 these variables is not meaningfully lower than the variability existing between subjects
275 (Pestaña-Melero et al., 2018).
276
277   The generally low correlations between V_{1RM} and V_{last} for both BP variants ($r \leq$
278 0.37) indicates that the value of one variable cannot be inferred from the other.
279 Similarly, as it was previously shown by García-Ramos et al. (2018), no significant
280 correlations were observed between the 2 BP variants for V_{1RM} ($r = -0.01$). Only the
281 value of V_{last} was moderately correlated between the 2 BP variants ($r = 0.46$), revealing
282 that participants with a higher V_{last} in one BP variant also tended to have a higher V_{last} in
283 the other BP variant. These results provide additional support for the use of the same
284 minimal velocity threshold (i.e. V_{1RM}) for all participants when predicting the 1RM from
285 the individualized L-V relationship during the BP exercise performed in a Smith
286 machine. The lack of differences between the BP variants for the magnitudes of V_{1RM}
287 and V_{last} simplifies this approach because the same minimal velocity threshold could be
288 used for both BP variants. According to the results of this and previous studies, the

289   minimal velocity threshold should be set at 0.17 m·s⁻¹ (García-Ramos et al., 2018;
290   García-Ramos et al., 2019; González-Badillo & Sánchez-Medina, 2010; Sánchez-
291   Medina, González-Badillo, Pérez, & Pallarés, 2014). However, Helms et al. (2017)
292   reported in 15 powerlifters (12 men and 3 women) a lower V_{1RM} during the free-weight
293   BP exercise that was performed using a "press" command to simulate a powerlifting
294   competition. Therefore, additional research should be conducted with different variants
295   of the free-weight BP and more trained populations to elucidate whether the minimal
296   velocity threshold recommended in the present study can also be applicable to these
297   conditions.
298
299   In the present study we also explored the influence of 1RM strength on the
300   values of V_{1RM} and V_{last}. Based on the lower V_{1RM} reported by Helms et al. (2017) in
301   powerlifters during the free-weight BP (0.10 ± 0.04 m·s⁻¹) compared to the V_{1RM}
302   reported by Loturco et al. (2017) in rugby players and combat athletes (0.17 m·s⁻¹), we
303   hypothesized that the 1RM strength would be negatively associated with V_{1RM} and V_{last}.
304   This hypothesis was somewhat supported with a significant, albeit weak, negative
305   correlation between the 1RM load and V_{1RM} (r = -0.33) and V_{last} (r = -0.17). This result is
306   also in line with the findings of Ormsbee et al. (2019) who reported a slower V_{1RM} for
307   experienced benchers (0.14 ± 0.04 m·s⁻¹) compared to novice benchers (0.20 ± 0.05
308   m·s⁻¹).Therefore, although based on these results a slightly lower minimal velocity
309   threshold could be obtained by stronger subjects, the low reliability and low correlations
310   found in the present study for V_{1RM} and V_{last} suggest that it may not be necessary to
311   modify the minimal velocity threshold based on the 1RM strength values when the
312   bench press is performed in a Smith machine. Finally, we also explored the influence of
313   the number of repetitions performed during the sets to failure on V_{last}, and we observed
314   a relatively weak negative association (r = -0.23), indicating that a slightly lower V_{last} can
315   be obtained when higher number of repetitions are performed. Therefore, in the case
316   that coaches are interested in determining V_{last}, we recommended that V_{last} is derived
317   from a set to failure of at least 5 repetitions.
318
319   A limitation of the present study is that the 1RM was directly assessed only once
320   for each BP variant and, therefore, it was not possible to compare the reliability between
321   V_{1RM} and V_{last}. However, the lower correlations between the BP variants observed in this
322   study for V_{1RM} compared to V_{last} suggest that the V_{1RM} could also be less reliable than
323   V_{last}. This would corroborate the results of previous studies that have reported a poor
324   reliability for the V_{1RM} during the BP (Pestaña-Melero et al., 2018) and other resistance
325   training exercises such as the back squat (Banyard, Nosaka & Haff, 2017), deadlift (Ruf,
326   Chery & Taylor, 2018), or bench pull (García-Ramos et al., 2019). Another limitation is
327   that the BP was performed in a Smith machine, while the vast majority of athletes use
328   the free-weight BP during their resistance training programs. In the current study, the
329   Smith machine was used to simplify the testing procedure and to improve the
330   reproducibility of velocity readings. Thus, it is plausible that the reliability of V_{last} and
331   V_{1RM} may be even lower if the BP is performed with free-weights due to the additional
332   control required and horizontal movements characterizing the free weight BP. Finally,
333   the sample of this study was composed of males with a mean of 1.3 years of experience
334   with the BP exercise and, therefore, it is possible that the accuracy of V_{1RM} and V_{last}

335 could increase when testing participants with more experience. Future studies should
336 compare the magnitude of V_{1RM} and V_{last} as well as the reliability of these variables
337 between individuals with different training backgrounds to shed light on this topic.
338

Conclusions

340 The reliability of V_{last} was below the threshold of acceptable reliability for both BP
341 variants. V_{last} was always significantly lower than V_{1RM}, while no significant differences
342 between the BP variants were observed for V_{1RM} or V_{last}. V_{last} was more correlated
343 between the BP variants than V_{1RM}. The correlations between V_{1RM} and V_{last} ranged
344 from small (paused BP) to moderate (touch-and-go BP). An inverse, but generally weak,
345 association was observed between V_{last} and the number of repetitions performed to
346 failure and the 1RM load, as well as between the V_{1RM} and the 1RM load. Therefore,
347 even though V_{last} could be a more appropriate indicator of the minimal velocity threshold
348 than V_{1RM}, our results (i.e. low reliability, lack of differences in magnitude and only
349 moderate association between the BP variants) also suggest that a general V_{1RM} could
350 be more appropriate to estimate the 1RM during the BP exercise performed in a Smith
351 machine.
352

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355

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439

440 **Figure legends**

441 **Figure 1.** Association (A and C) and comparison (B and D) between the velocity of the
442 1-repetition maximum (V_{1RM}) and the velocity achieved during the last repetition of sets
443 to failure (V_{last}) during the paused (A and B) and touch-and-go (C and D) bench press
444 (BP) exercises. *r*, Pearson's correlation coefficient; *p*, p-value obtained from paired
445 sample's t tests; ES, Cohen's *d* effect size [(V_{1RM} mean - V_{last} mean)/SDboth].

446

447 **Figure 2.** Association (A and C) and comparison (B and D) between the paused bench
448 press (BP) and the touch-and-go BP for the velocity of the 1-repetition maximum (V_{1RM};
449 A and B) and the velocity achieved during the last repetition of sets to failure (V_{last}; C
450 and D). *r*, Pearson's correlation coefficient; *p*, p-value obtained from paired sample's t
451 tests; ES, Cohen's *d* effect size [(paused BP mean – touch-and-go BP mean)/SDboth].

452

453 **Figure 3.** Bland-Altman plots showing the differences between the velocity of the 1-
454 repetition maximum (V_{1RM}) and the velocity achieved during the last repetition of sets to
455 failure (V_{last}) during the paused bench press (BP) (A) and the touch-and-go BP (B).
456 Each plot depicts the systematic bias and 95% limits of agreement (± 1.96 SD; dashed
457 lines), along with the regression line (solid line). The systematic bias ± random error
458 together with the strength of the relationship (r^2) are depicted in each plot.

459

460 **Figure 4.** Relationship between the number of repetitions performed to failure and V_{last}
461 (A), 1-repetition maximum and V_{last} (B), and 1-repetition maximum and V_{1RM} (C). V_{last},
462 velocity of the last repetition performed during sets of repetitions to failure; V_{1RM}, velocity
463 achieved during the 1-repetition maximum trial. The regression equation and the
464 Pearson's correlation coefficient (*r*) are depicted.

Figure 1

Association and comparison between the velocity of the 1-repetition maximum and the velocity achieved during the last repetition of sets to failure

Association (left hand panels) and comparison (right hand panels) between the velocity of the 1-repetition maximum (V_{1RM}) and the velocity achieved during the last repetition of sets to failure (V_{last}) during the paused (upper panels) and touch-and-go (lower panels) bench press (BP) exercises. *r*, Pearson's correlation coefficient; *p*, p-value obtained from paired sample's t tests; ES, Cohen's *d* effect size [(V_{1RM} mean - V_{last} mean)/SDboth].

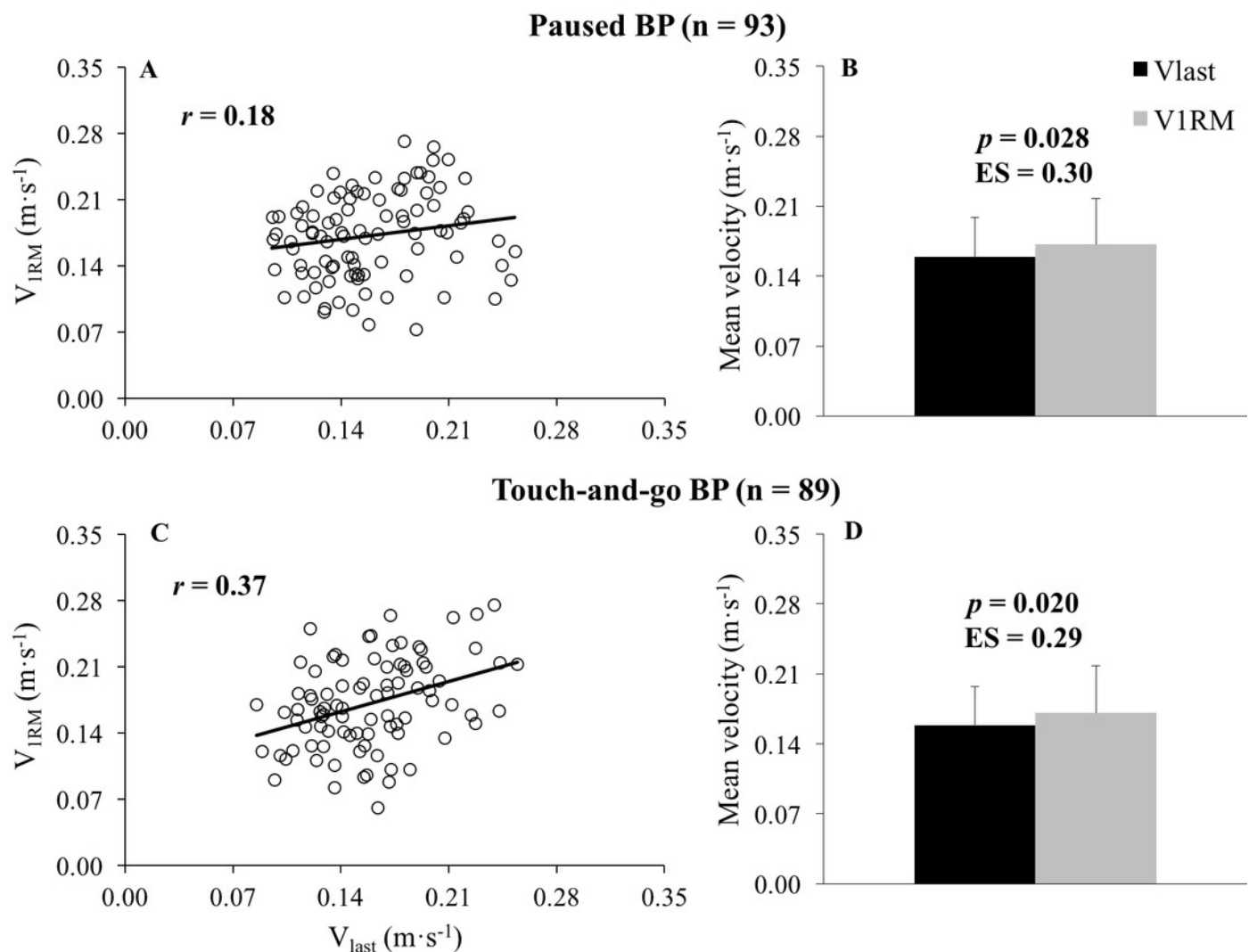



Figure 2

Association and comparison between the paused bench press and the touch-and-go bench press for the velocity of the 1-repetition maximum and the velocity achieved during the last repetition of sets to failure

Association (left hand panels) and comparison (right hand panels) between the paused bench press (BP) and the touch-and-go BP for the velocity of the 1-repetition maximum (V_{1RM}; upper panels) and the velocity achieved during the last repetition of sets to failure (V_{last}; lower panels). *r*, Pearson's correlation coefficient; *p*, p-value obtained from paired sample's t tests; ES, Cohen's *d* effect size [(paused BP mean – touch-and-go BP mean)/SDboth].

V_{1RM} (n = 86)

V_{last} (n = 86)

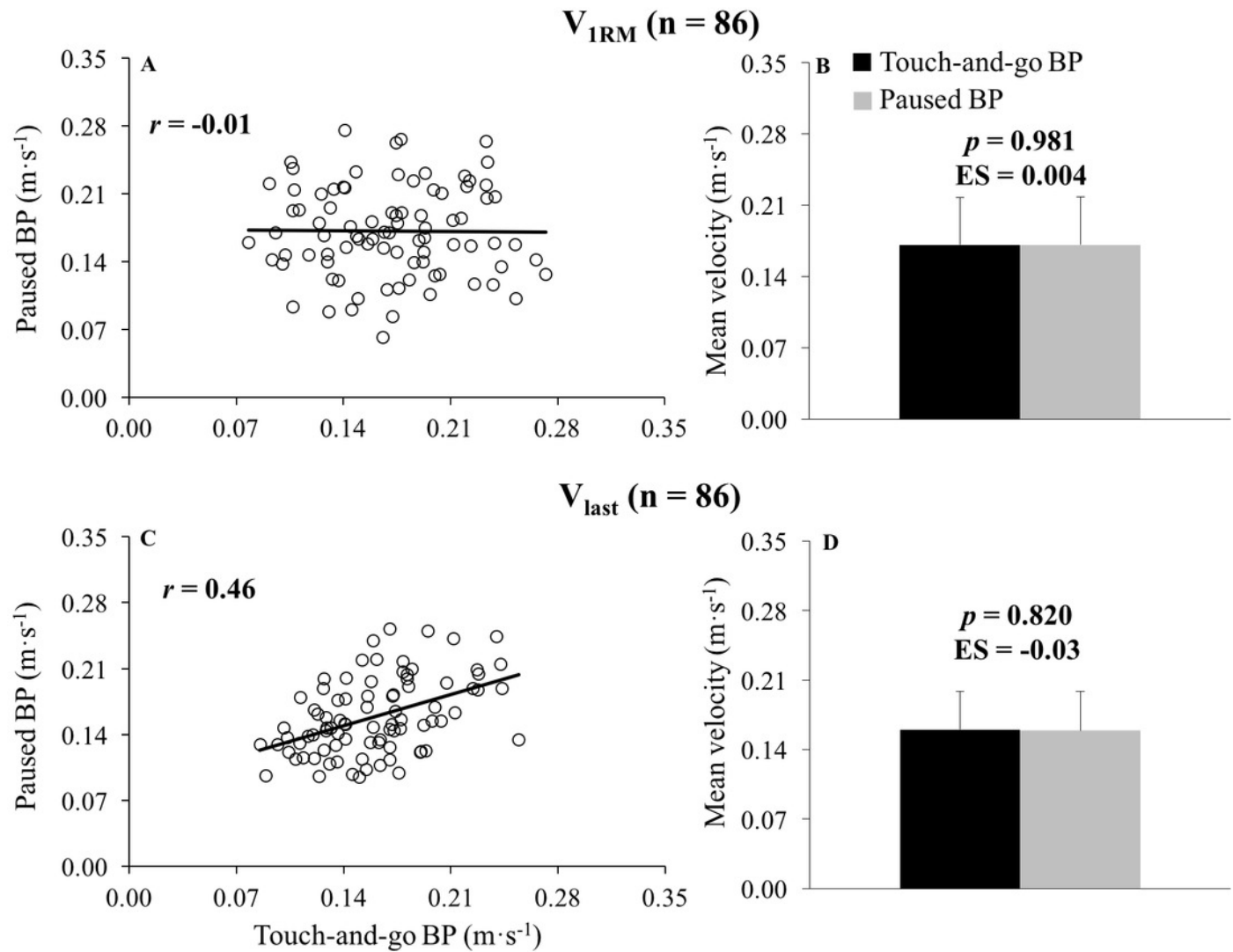



Figure 3

Differences between the velocity of the 1-repetition maximum and the velocity achieved during the last repetition of sets to failure during the paused bench press (BP) and the touch-and-go BP.

Bland-Altman plots showing the differences between the velocity of the 1-repetition maximum (V_{1RM}) and the velocity achieved during the last repetition of sets to failure (V_{last}) during the paused bench press (BP) (upper panel) and the touch-and-go BP (lower panel). Each plot depicts the systematic bias and 95% limits of agreement (± 1.96 SD; dashed lines), along with the regression line (solid line). The systematic bias ± random error together with the strength of the relationship (r^2) are depicted in each plot.

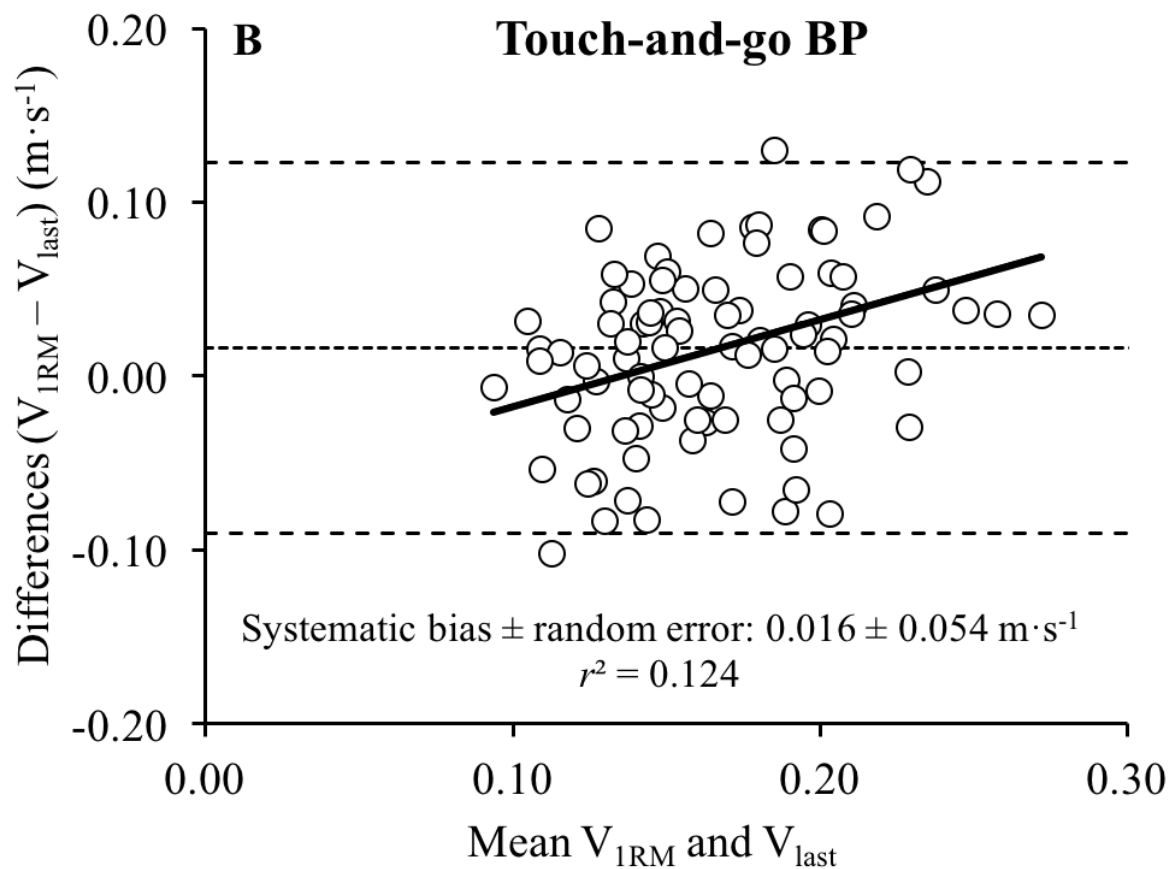
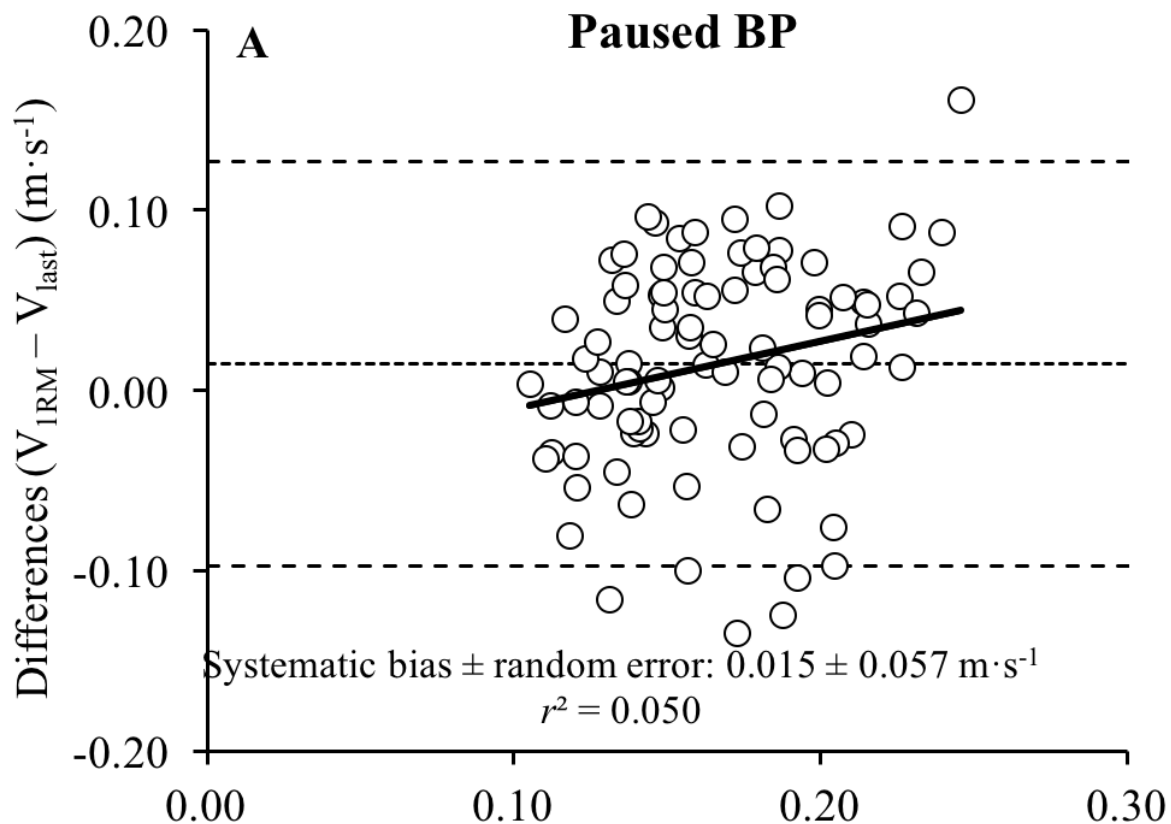
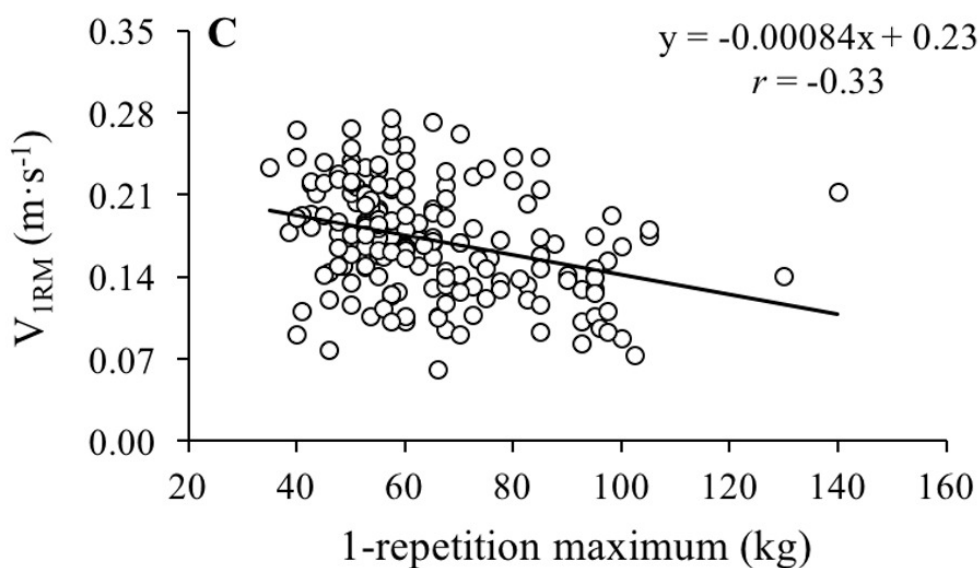
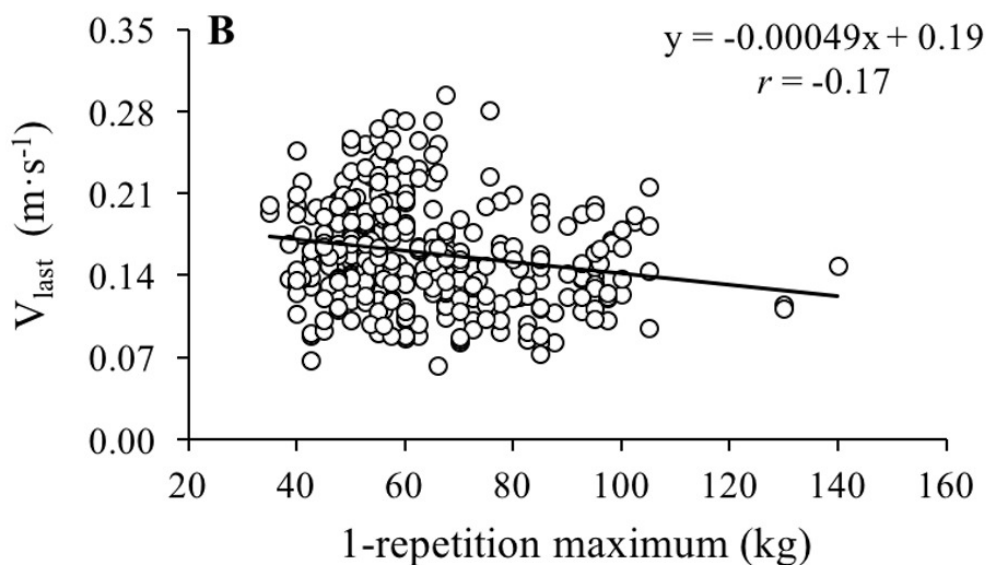
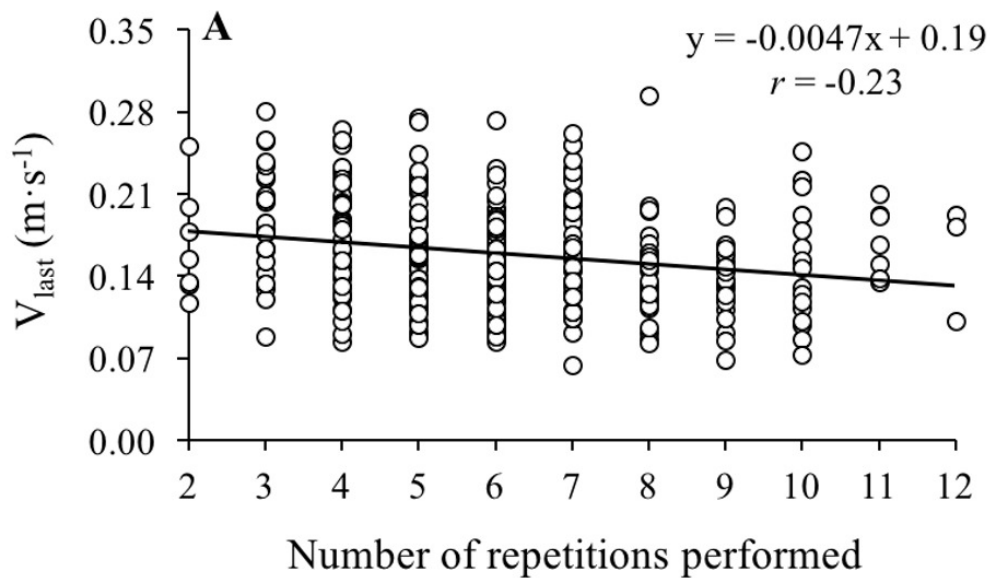



Figure 4

Relationship between the number of repetitions performed to failure and velocity of the last repetition performed during sets of repetitions to failure (V_{last}), 1-repetition maximum and V_{last}, and 1-repetition maximum and velocity

Relationship between the number of repetitions performed to failure and V_{last} (upper panel), 1-repetition maximum and V_{last} (middle panel), and 1-repetition maximum and V_{1RM} (lower panel). V_{last}, velocity of the last repetition performed during sets of repetitions to failure; V_{1RM}, velocity achieved during the 1-repetition maximum trial. The regression equation and the Pearson's correlation coefficient (*r*) are depicted

Reliability of mean concentric velocity values achieved during the last repetition of sets to failure during the paused and touch-and-go bench press exercises

BP, bench press; *p*, p-value; CV, coefficient of variation; ICC, intraclass correlation coefficient; SEM, standard error of measurement; 95% CI, 95% confidence interval

1 **Table 1.** Reliability of mean concentric velocity values achieved during the last repetition of sets
2 to failure during the paused and touch-and-go bench press exercises.

Exercise	Set 1 (m·s⁻¹)	Set 2 (m·s⁻¹)	p	CV (95% CI)	ICC (95% CI)	SEM (m·s⁻¹)
Paused BP (n = 93)	0.161 (0.045)	0.157 (0.045)	0.303	18.3% (16.0%, 21.4%)	0.58 (0.43, 0.70)	0.029
Touch-and-go BP (n = 89)	0.162 (0.046)	0.156 (0.043)	0.266	20.4% (17.8%, 24.0%)	0.48 (0.30, 0.62)	0.032

4 BP, bench press; p, p-value; CV, coefficient of variation; ICC, intraclass correlation coefficient;
5 SEM, standard error of measurement; 95% CI, 95% confidence interval.