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The Effects of Combining PETTLEP Imagery and Action Observation on Bicep Strength: A
Single-Case Design.

21 **The Effects of Combining PETTLEP Imagery and Action Observation on Bicep**
22 **Strength: A Single-Case Design**

23 **Abstract**

24 The PETTLEP model of motor imagery (Holmes & Collins, 2001) has been shown
25 to be effective in enhancing strength performance. With recent literature discussing
26 the shared neural substrates between imagery and action observation, this study
27 investigated whether PETTLEP imagery would improve bicep strength both with
28 and without an additional observational aid. Using a single-case design, four
29 participants completed a baseline phase followed by PETTLEP imagery with and
30 without an observation aid in a counterbalanced manner. Weekly bicep curl 1
31 repetition maximum (1 R.M.) was used as the performance measure. Results
32 indicated that using an observational aid in conjunction with PETTLEP imagery
33 can aid performance, but not to a greater degree than PETTLEP imagery alone. This
34 indicates that observational aids may not be an essential addition to imagery
35 interventions, but their inclusion is not detrimental. The study highlights further the
36 benefit of using PETTLEP imagery for enhancing strength performance, which
37 should be considered by practitioners delivering resistance training programs.
38 Future research could further explore the role of observation when combined with
39 imagery to assess the effect on strength in an athletic population.

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44 Motor imagery is the act of producing an internal representation of movement, typically
45 without generating any physical output (Mulder, 2007). Improvements in strength performance
46 following the use of motor imagery are well documented in the literature (see Slimani, Tod,
47 Chaabene, Miarka, & Charmari, 2016 for a review). For example, Yue and Cole (1992) found
48 that a four-week training program using either maximal isometric contractions or imagined
49 maximal isometric contractions produced strength gains of 29.8% and 22% respectively in the
50 abductor digiti minimi muscle. A more recent study (Wright & Smith, 2009) on a larger muscle
51 group (elbow flexors) also showed a strength gain of 23% through imagery training.

52 Such findings are potentially of great value to those involved in strength training.
53 However, the question of how to conduct imagery to produce optimal strength gains also needs
54 to be considered. The PETTLEP model (Holmes & Collins, 2001) has recently been used to
55 guide imagery interventions with strength tasks (for example, see Wakefield & Smith, 2011).
56 This model was derived from a mix of cognitive psychology, sport psychology and
57 neuroscience research, the latter indicating that imagery produces activity in similar areas of
58 the brain to those active during movement execution. Consequently, the model proposed that a
59 ‘functional equivalence’ exists between imagery and physical performance of a motor skill.
60 PETTLEP is an acronym, with each letter standing for a practical consideration when designing
61 and constructing an imagery intervention. These are Physical, Environment, Task, Timing,
62 Learning, Emotion and Perspective (see Holmes & Collins, 2002, for a detailed review). Whilst
63 it is not essential, and indeed not always advised, to incorporate all of these considerations at
64 once, several studies have demonstrated the effectiveness of PETTLEP imagery compared to
65 more traditional imagery techniques focusing primarily on visual imagery and often conducted
66 in a seated or lying position (e.g., Smith, Wright, Allsopp & Westhead, 2007; Wright & Smith,
67 2007). PETTLEP-based imagery has also been shown to improve performance of strength tasks
68 (Lebon, Collet & Guillot, 2010; Wakefield & Smith, 2011; Wright & Smith, 2009).

69 Like imagery, a large body of literature exists supporting efficacy of action observation
70 for improving performance in a variety of motor skills (Ste-Marie, Law, Rymal, O, Hall, &
71 McCullagh, 2012), including strength-based tasks (Ram, Riggs, Skaling, Landers, &
72 McCullagh, 2007). Action observation is defined as observing others to create an internal
73 representation of perceived actions (Gallese, 2001). Several investigators have shown that
74 imagery and action observation both activate the motor regions of the brain in a similar manner
75 (Grèzes & Decety, 2001; Munzert, Zentgraf, & Vaitl, 2008) and brain mapping studies have
76 shown that similar neural areas are activated during the physical execution or imaged/observed
77 mental simulation of motor actions (Filimon, Nelson, Hagler, & Sereno, 2007; Grèzes &
78 Decety, 2001; Hardwick, Caspers, Eickhoff, & Swinnen, 2018).

79 More recently, researchers have begun to focus on the effects of engaging in imagery
80 and action observation simultaneously on activity in the motor system (see Eaves, Riach,
81 Holmes, & Wright, 2016 and Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013 for reviews).
82 This research indicates that the simultaneous combination of imagery and action observation
83 is associated with increased activity in motor regions of the brain, compared to the single use
84 of either technique (e.g., Sakamoto, Muraoka, Mizuguchi, & Kanosue, 2009; Villiger et al.,
85 2013; Wright, Williams, & Holmes, 2014). As such, researchers have recently argued that
86 combined imagery and action observation interventions may be more effective for improving
87 sport performance, compared to the independent use of either technique (Holmes & Wright,
88 2017). To date, however, little evidence exists to support the efficacy of combined imagery and
89 action observation interventions in enhancing motor skill performance.

90 One area where combined imagery and action observation interventions may prove
91 particularly beneficial is in improving strength performance. Wright and Smith (2009) and
92 Scott, Taylor, Chesterton, Vogt, and Eaves (2017) have shown the potential benefits of
93 combined imagery and action observation for improving strength performance in group-based

118 and previous weight training experience and only those who were not currently engaged in a
119 weight-training program were included.

120 **Measures**

121 **Movement Imagery Questionnaire 3 (MIQ-3; Williams et al., 2012).** The MIQ-3 is
122 a 12-item inventory that assesses an individual's capability to perform internal visual, external
123 visual, and internal kinesthetic imagery of four movements: A knee lift, jump, arm movement
124 and toe touch. As per the questionnaire instructions, participants physically performed each of
125 the requested actions a single time. Following execution of the action, participants were
126 instructed to image the movement, using an internal visual, external visual, or kinesthetic
127 modality. Participants then rated the ease or difficulty with which they completed the imagery
128 on a 7-point Likert type scale ranging from 1 (*very hard to see/feel*) to 7 (*very easy to see/feel*).
129 The predictive validity of MIQ-3 has been demonstrated by Williams et al. (2012), who showed
130 a strong relationship between MIQ-3 scores and observational learning use.

131 **Imagery diary.** Participants were provided with an imagery diary, which they were
132 encouraged to complete after each imagery session to confirm that they had performed their
133 imagery. They were instructed to note down the date and time of their imagery session, and
134 any difficulties they experienced while performing their imagery, as well as any deviations
135 from normal patterns, such as amount of sleep and any heavy lifting completed.

136 **Equipment**

137 **Bicep curl machine.** A bicep curl machine (Techno Gym Arm Curl) was used. The
138 resistance varied from 5kg to 68.75kg with 1.25kg increments. Participants received
139 instructions on good technique as well as a demonstration before the start of each baseline
140 testing session from a qualified instructor experienced with using this machine. This was to

141 ensure their safety and to encourage consistency with their technique so that each testing
142 session was performed in a similar manner.

143 **Design**

144 The performance measure used was a one repetition maximum (1 R.M.) lift on the bicep
145 curl machine. A baseline design of three collection points was used, as previous research
146 (White, 1974) indicated that this was the minimum required to produce a baseline with
147 sufficient stability. Each intervention was then administered for four weeks, in a
148 counterbalanced manner, with 1 R.M. performance being completed at the end of each week
149 during the baseline and intervention phases (resulting in a total of 11 measures being performed
150 by each participant, see Table 1). Previous imagery studies have found improved strength
151 resulting from as few as two weeks of imagery practice (Shackell & Standing, 2007), and the
152 total number of imagery sessions in the present study mirrored that of Wright and Smith's
153 (2009) study, which found an increase in 1 R.M. strength using imagery alone.

154

155 **Procedure**

156 Following institutional ethical approval, and prior to commencement of the study, all
157 participants provided written informed consent after being given information on the purpose of
158 the study and its requirements. Participants then completed the MIQ-3, the results of which
159 indicated that all participants had good imagery ability, with each participant displaying high
160 scores for most subscales (see Table 1). Following the first baseline 1 R.M. testing session,
161 participants completed a set of 6-10 repetitions to failure on the bicep curl machine in order to
162 produce the observation video. Here, an individualized video of these repetitions was taken
163 from above for each participant; an angle used to simulate an internal visual perspective (see

164 Figure 1). This video also included typical noises from the gym, including talking and
165 background music.

166 After completing the three-week baseline period, participants received PETTLEP
167 imagery instructions and training. Firstly, response training (Lang, Kozak, Miller, Levin, &
168 McLean, 1980) was carried out. Each participant started this by generating a simple image of
169 himself sitting at the bicep curl machine in the gym, with attention being drawn to aspects of
170 the imaged scenario that he found relatively easy to image. Additional details relevant to the
171 scenario were then progressively added according to the responses of the participant (e.g.,
172 different sensory modalities, physiological and emotional responses). This continued until a
173 complete and vivid imagery experience was produced that the participant stated he was happy
174 with. The completed script was then used by the participant to practice imaging, which allowed
175 any details he felt were missed first time round to be included, as well as allowing the altering
176 of elements such as the wording to make the script as personalized and easy to read as possible.
177 An example script was as follows:

178 “You are about to perform a set of repetitions to failure on the bicep curl machine. Prior
179 to sitting in the machine you gradually clear your mind of all other concerns, ignoring the other
180 gym-goers and the music blaring in the background. Instead, you focus on the task ahead of
181 you, pushing your biceps to the limit. When you’re ready you adjust the seat height and then
182 place the pin in the weight stack, noting that you are about to set a personal best. You start to
183 feel your heart pump faster already and you feel your palms become sweaty in anticipation.
184 You feel excited but a little nervous as you think about lifting more weight than you have ever
185 done before. You sit in the machine and grasp the handles, feeling the knurled surface rub
186 against your skin. You start to slowly curl the handles towards you and feel your biceps stiffen
187 as the handles come up, with a feeling of triumph as you realise you can easily handle this
188 weight. You then slowly lower the handles and hear the soft ‘clunk’ as the weight descends on
189 the stack. You perform each repetition slowly and smoothly, and your biceps begin to burn but
190 you keep lifting as you are determined to do more repetitions than ever before. Your heart is
191 now pounding and your biceps are burning, but you slowly grind that weight upwards for
192 another repetition. On the next repetition your biceps are on fire, you are really feeling the burn
193 but will not give up! You pull that weight up as if your life depended on it, you can feel sweat
194 stinging your eyes and your heart feels like it is going to burst out of your chest, but you keep
195 going. Finally, you try to lift the weight and no matter how hard you try, the handles will not
196 budge an inch. Your whole body is shaking now as you try to get that one last repetition, and
197 you feel the cold sensation of the sweat rolling down your skin and your biceps now feel like
198 an inferno. Knowing that you have given 100% and couldn’t do any more, you get a great

199 feeling of satisfaction as you let go of the handles. You notice the great pump on your biceps
200 as they are filled blood: another personal best!”

201 Participants were asked to complete imagery from a first person perspective, to reflect
202 that of the video and replicate the pre- and post-test performance perspective. Using first person
203 visual perspective imagery mirrored the Wakefield and Smith (2011) and Wright and Smith
204 (2009) studies, which both showed improved bicep curl strength.

205 All aspects of the PETTLEP model of imagery were addressed through the
206 interventions.

207 Physical: For the physical component, participants were instructed to mentally simulate
208 the kinesthetic sensations experienced when performing a bicep curl. Participants were
209 instructed to sit on a chair with their arms down by their sides, while holding onto cylindrical
210 objects similar in diameter to the bicep curl machine handles, a technique previously suggested
211 by Holmes and Collins (2001). In addition, participants wore clothing similar to that worn when
212 performing their actual 1 R.M. tests (i.e., if they wore a t-shirt in the test then they also wore a
213 t-shirt when performing the imagery).

214 Environment: Whether imagery training is conducted in the performance environment
215 or not has varied in previous studies using PETTLEP imagery. However, because previous
216 studies (i.e., Wakefield & Smith, 2011) found promising results with PETTLEP imagery
217 performed at home, it was decided to replicate this procedure. Nevertheless, efforts were made
218 to keep the imagery PETTLEP-centered, including the environment element of the model.
219 Participants were encouraged to concentrate on their physical and psychological responses to
220 the training situation and relevant stimuli from the gym environment (for example lighting and
221 temperature) and these were included in the imagery scripts and associated videos.

222 Task: The task element of PETTLEP imagery centered on imaging bicep curls on the
223 machine to emulate the performance measure as closely as possible, and ensuring the

224 appropriate attentional focus. Response training concentrated on each participant's attention
225 during the performance of the baseline bicep curls, which allowed the scripts to be
226 individualized as per appropriate skill level and attentional focus of each participant. For
227 example, one participant might concentrate on gripping the handles of the machine and moving
228 the weight while another might be concentrating more on feeling the contraction of the bicep
229 muscles, depending on his level of experience and personal preference.

230 Timing: Participants were encouraged to perform imagery in 'real time' with the
231 cadence set at a 1-second concentric and 3-second eccentric muscle action. In the video-absent
232 intervention block, participants were instructed to try to recall the speed at which they
233 performed their repetitions to failure in the baseline testing phase. In the intervention block
234 where the observational video was used, timing of the imagery mirrored that seen in the
235 individual videos.

236 Learning: The learning element was addressed by requiring the participants to go over
237 their imagery scripts again after completion of the first intervention block. Olsson and Nyberg
238 (2010) discussed the importance of physical experience as a factor that could influence imagery
239 ability, therefore the imagery scripts were created after the final baseline-testing phase,
240 allowing participants time to become accustomed to the bicep curl movement. Without this
241 period of acclimatization to the physical movement, after only a few sessions the content of
242 their imagery scripts may have needed to drastically change to stay relevant to the participants'
243 experience and skill level.

244 Emotion: Response training was used to engage the emotional component of the model,
245 by recording emotional responses during the baseline testing phase and encouraging
246 participants to include these emotions in their imagery practice. For example, one participant

247 recorded that he felt satisfaction after completing his last repetition, whilst another felt relieved.
248 These, and other similar positive emotions, were included in the imagery scripts.

249 Perspective: In the video intervention block, the perspective element was addressed by
250 the first person perspective displayed on the video, which showed participants performing
251 bicep curls of their repetitions to failure recorded in the baseline testing phase. This visual
252 perspective was chosen as it has been reported to be more effective for improving strength
253 performance than imagery from third person visual perspectives (Slimani et al., 2016). In the
254 video-absent intervention block, participants noted down visual cues from their baseline testing
255 phase, and were encouraged to concentrate on these visual cues when performing their imagery
256 training. These visual cues included details external to the participant such as gym equipment
257 in view of the participant as well as seeing the movement of hands and arms during execution
258 of the bicep curl.

259 Over the 8 weeks of the interventions, participants imaged themselves performing two
260 sets of 6-10 repetitions to failure either with or without the observational video, depending on
261 the intervention. Participants were required to perform each intervention three times a week for
262 four weeks, before commencing the next intervention phase, in a counterbalanced order.
263 Participants performed a 1 R.M. at the end of each week to monitor weekly progress. As
264 previously indicated, participants' imagery diaries also served as manipulation checks,
265 ensuring that participants had correctly performed their imagery as well as discussing
266 deviations from normal behaviors such as sleeping patterns and physical exertion. Details of
267 any issues or difficulties with following the imagery interventions were also noted. In the event,
268 all participants completed the diaries as instructed. These showed that the participants reported
269 completing their imagery as instructed, and no difficulties, or confounding factors such as great
270 physical exertion, were noted.

271 **Data Analysis**

272 The data from the participants' individual 1 R.M. scores were plotted onto a graph.
273 Visual inspection is a commonly used form of analysis in single-case designs (Kinugasa, Cerin,
274 & Hooper, 2004). However, in order to produce a more robust analysis, lines representing the
275 mean for the baseline, total intervention and each intervention phase, in addition to trend lines,
276 were added. To further extend the analysis, binomial statistics were carried out. These tests
277 involve calculations of the number of data points above and below trend lines in order to
278 establish any significant differences, and were conducted in line with previous single-case
279 design studies (Callow, Hardy, & Hall, 2001; Wakefield & Smith, 2011). Furthermore, effect
280 sizes were calculated using the formula proposed by Kromrey and Foster-Johnson (1996), and
281 previously used in single case study designs of a similar nature. Based upon previous data,
282 Parker and Vannest (2009) examined effect sizes for single-case designs and proposed that an
283 effect size of $<.87$ is small, $.87-2.67$ is medium and >2.67 is large.

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Results

287 **Participant 1 – Performance Data**

288 Participant 1's mean score in the baseline phase was 45.83 kg (SD = 1.61), with a
289 gradient of $x.83$. This increased to 53.13 kg (SD = 1.61, gradient $x.19$) in the first intervention
290 phase (imagery + video), and remained at 53.13 kg (SD = 1.61, gradient $x-.75$) in the second
291 intervention phase (imagery). The mean score for the overall intervention phases combined
292 was 53.13 kg (SD = 1.49), an increase of 16.36% from the baseline measure. The scores
293 recorded each week as well as the phase means can be seen in Figure 2. The black dots joined
294 by thick black lines represent the weekly 1 R.M. scores, with the thin grey lines in each segment

295 representing the mean for each phase. Binomial tests showed a significant increase in 1 R.M.
296 strength when comparing the overall post intervention data with the projected baseline data (p
297 $< .001$). However, no significant differences were apparent when comparing the second
298 intervention (imagery) to the projected first intervention (imagery + video) data ($p > .05$).
299 Effect sizes were calculated, comparing mean data from the baseline and intervention periods.
300 These were 6.19 and 6.72 from baseline to the imagery with video intervention phase, and to
301 the imagery intervention phase respectively. There was an effect size of .45 from the imagery
302 with video intervention phase to the imagery intervention phase. The effect size from baseline
303 to the combination mean of both intervention phases was 6.36.

304 **Participant 2 – Performance Data**

305 Participant 2's mean score in the baseline condition was 48.75 kg (SD = 1.02), with a
306 gradient of x.83. This increased to 53.44 kg (SD = 1.62, gradient x.42) in the first intervention
307 phase (imagery), followed by 57.94 kg (SD= 1.23, gradient x.59) in the second intervention
308 phase (imagery with video). The mean score for the overall intervention phase was 55.69 kg
309 (SD = 2.67), an increase of 14.24% from the baseline measure (see Figure 3). Binomial tests
310 showed a significant increase in 1 R.M. strength when comparing the overall post-intervention
311 data with the projected baseline data ($p < .001$). However, no significant differences were
312 apparent when comparing the second intervention (imagery + video) to the projected first
313 intervention (imagery) data ($p > .05$). Effect sizes were calculated comparing mean data from
314 the baseline and intervention periods. These were 4.59 and 9.00 from baseline to the imagery
315 intervention phase and to the imagery with video intervention phase, respectively. There was
316 an effect size of 2.78 from the imagery intervention phase to the imagery with video
317 intervention phase. The effect size from baseline to the combination mean of both intervention
318 phases was 6.80.

319 **Participant 3 – Performance Data**

320 Participant 3's mean score in the baseline phase was 43.08 kg (SD = 2.79), with a
321 gradient of x2.25. This increased to 51.25 kg (SD = .88, gradient x.19) in the first intervention
322 phase (imagery + video), followed by 54.06 kg (SD = 1.62, gradient x.83) in the second
323 intervention phase (imagery). The mean score from the two intervention phases combined was
324 52.66 kg (SD = 1.92), an increase of 22.24% from the baseline measure (see Figure 4).
325 Binomial tests showed no significant increase in 1 R.M. strength when comparing the overall
326 post intervention data with the projected baseline ($p > .05$). However, a significant increase
327 was apparent in bicep strength in the imagery phase, compared to the projected imagery with
328 video data ($p < .05$). Effect sizes were calculated comparing mean data from the baseline and
329 intervention periods. These were 2.93 and 3.94 from baseline to the imagery with video
330 intervention phase and the imagery intervention phase respectively. There was an effect size of
331 3.18 from the imagery with video phase to the imagery phase. The effect size from baseline to
332 the combination mean of both intervention phases was 3.44.

333

334 **Participant 4 – Performance Data**

335 Participant 4's mean score in the baseline phase was 36.25 kg (SD = 1.02), with a
336 gradient of x.42. This increased to 39.17 kg (SD = .59, gradient x.00) in the first intervention
337 phase (imagery), followed by 42.5 kg (SD = .88, gradient x.45) in the second intervention phase
338 (imagery + video). The mean score from the two intervention phases combined was 41.07 kg
339 (SD = 1.82), an increase of 13.3% from the baseline measure (see Figure 5). Binomial tests
340 showed a significant increase in 1 R.M. strength when comparing the overall post intervention
341 data with the projected baseline ($p < .001$). However, no significant differences were apparent
342 when comparing the second intervention (imagery + video) to the projected first intervention

343 (imagery) data ($p > .05$). Effect sizes were calculated comparing mean data from the baseline
344 and intervention periods. These were 2.86 and 6.12 from baseline to the imagery intervention
345 phase and the imagery with video intervention phase respectively, with an effect size of 5.66
346 from the imagery intervention phase to the imagery with video intervention phase. The effect
347 size from baseline to the combination mean of both intervention phases was 4.72.

348 **Discussion**

349 The results of the current study are in line with the first hypothesis as all participants
350 showed an improvement in bicep strength from baseline to the intervention phase. This finding
351 is supported by previous literature on the topic, as several studies have shown imagery to be an
352 effective technique in enhancing strength performance (Lebon et al., 2010; Wakefield & Smith,
353 2012; Wright & Smith, 2009; see Slimani et al., 2016 for a review). Within single case design
354 work, Barker, McCarthy, Jones and Moran (2011) explain that the number of times a result can
355 be replicated the more likely it is to be accurate. Furthermore, the fewer overlapping data points
356 between baseline and intervention phases, the higher the confidence we can have that an effect
357 has occurred (Barker et al., 2011). Three out of four participants showed an improvement in
358 bicep strength following the intervention phases, and across all participants, no data points in
359 the intervention phases overlapped with that participant's baseline data points. These findings
360 therefore provide an indication that bicep strength improved because of the imagery
361 interventions.

362 The neural mechanisms mentioned in the introduction may explain how PETTLEP
363 imagery enhanced 1R.M. performance. There is clear widespread activity of brain areas
364 associated with both motor imagery and action execution that overlap extensively with one
365 another (Grèzes & Decety, 2001; Hardwick, Caspers, Eickhoff, & Swinnen, 2018) to create
366 a superior performance. The subsequent facilitation of corticospinal excitability may also be

367 reflective of activity in the pre motor brain regions that connect to the primary motor cortex
368 (Fourkas, Bonavolontà, Avenanti, & Aglioti, 2008; Wright et al., 2014), derived from the
369 disturbance of the spinal motor neuron pool. This may result in enhanced performance as a
370 result of imagery interventions, providing a potential explanation of our findings. However, we
371 cannot confirm this from the current data, and thus future research combining imagery of
372 strength tasks and psychophysiological measures would be a welcome addition to the literature.

373 The significant differences apparent were in improvements from baseline to the overall
374 intervention period. Within this, in three of the four cases, there were no significant differences
375 in the efficacy of PETTLEP imagery and observation, compared to PETTLEP imagery alone.
376 These findings appear to conflict with the second hypothesis and suggest that both conditions
377 produced an efficacious effect on performance following a 4-week intervention period. Whilst
378 this finding is unexpected given previous research on the topic (e.g., Scott et al., 2017), it is
379 important to note that the weight lifted did increase for the two participants who were assigned
380 the combination of observation and imagery in the second intervention phase, and there were
381 positive performance trajectories in all cases for the combination intervention. In contrast, in
382 the two cases where the imagery intervention in isolation formed the second intervention phase,
383 it did not change the performance trajectory. This suggests that imagery in isolation had a
384 performance maintenance, rather than performance enhancing, effect. Therefore, had we
385 adopted a purely visual analysis, as is common in single-case research, we would have
386 concluded that our results unequivocally supported the dual use of combined imagery and
387 action observation. The statistical analyses employed here set the bar high in terms of the
388 burden of evidence, given the low number of data points and an n of 1. Thus, we should not
389 dismiss entirely the possible usefulness of the combined interventions. Rather, we would argue
390 that our findings suggest that consultants should offer athletes the opportunity to exercise a
391 preference for utilizing an additional observation aid when engaging in imagery interventions

392 for performance enhancement. That is, inclusion of an observational aid does not appear to be
393 always essential for maximizing strength gains from imagery, but neither would it reduce the
394 effectiveness of the intervention. This is crucial given the importance of the individualizing of
395 imagery scripts and practices for optimal results (Smith, Holmes, Collins, Whitemore, &
396 Devonport, 2001; Wilson, Smith, Burden, & Holmes, 2010).

397 The mean and trend results also indicate that the second intervention phase that the
398 participants completed was equally or more efficacious than the first, regardless of the ordering
399 of the interventions. Previous research has shown that physiological adaptations have the
400 potential to occur over a longer period than used in the present study. For example, Wakefield
401 and Smith (2011) found strength increases still occurring after 15 weeks of interventions using
402 imagery without physical practice. It is possible, therefore, that it was irrelevant which imagery
403 condition was being used, as both continued to improve bicep strength performance. The
404 participants who completed the combined intervention second demonstrated a further increase
405 in performance because of the added observational aid. However, lesser effects were seen for
406 the imagery intervention in the cases where this intervention was completed following the
407 combined intervention. There is also the potential that participants completing the combined
408 intervention phase first may have experienced a continued performance effect when completing
409 the imagery-only intervention (e.g., remembering more information about timing and
410 environment). Furthermore, owing to the untrained nature of the participant group, it is possible
411 that strength changes may have been amplified owing to the weekly 1 R.M test conducted.
412 Whilst this did not occur in previous studies that employed a similar design (e.g., Wakefield &
413 Smith, 2011), it remains a possibility. Future research should examine this with a trained
414 population which would likely be more consistent in baseline performance and therefore more
415 resilient to the effects of a weekly 1 R.M.

416 In the current study the effect sizes for each participant, from the baseline mean to the
417 combined intervention mean, ranged from 3.44 to 6.80, signifying a large effect on 1 R.M.
418 performance caused by the introduction of the intervention phases. This supports the
419 predictions of the first hypothesis, and additionally these results resemble those of previous
420 research, which have shown that PETTLEP imagery can be an effective method of improving
421 strength performance (Wright & Smith, 2009; Wakefield & Smith, 2011). Although treatments
422 did not show significant differences between PETTLEP imagery alone and PETTLEP imagery
423 combined with observation, the effect sizes exhibit intriguing results; these indicate that there
424 were discrepancies between interventions when compared to the baseline measure. For
425 example, participant 2 displayed an effect size of 9.00 for the imagery and observation
426 intervention and 4.59 for the PETTLEP imagery intervention. These results are interesting, as
427 Wright and Smith (2009) also observed comparable effect sizes in their study. This again
428 highlights the requirement for additional research examining the efficacy of PETTLEP
429 imagery, action observation and combined interventions on performance.

430 In conclusion, the results offer further support to previous studies regarding the use of
431 the PETTLEP model as a framework when constructing imagery interventions in order to
432 improve strength performance (Wakefield & Smith, 2011; Wright & Smith, 2009). Whilst the
433 statistical analyses in the present study did not confirm that the addition of an observational aid
434 significantly improved the effectiveness of the imagery interventions, visual analyses did
435 suggest that it may improve the rate of strength gains when compared to PETTLEP imagery
436 alone. Regardless of whether an observational aid has a 'direct hit' effect on performance, it
437 appears that the use of observation during imagery can certainly help to provide a strong
438 PETTLEP basis to the intervention, most notably the environment, timing and perspective
439 aspects; this is particularly so when it is impractical for participants to perform imagery in the
440 performance environment. The results of this study have important implications for imagery

441 use and optimizing strength training benefits. When devising imagery interventions, coaches
442 and athletes should provide detailed PETTLEP-based instructions, specifically those outlined
443 within the current literature (e.g., Wakefield & Smith 2012). Evidence from both this study and
444 the emerging literature suggest that the combination of PETTLEP imagery and action
445 observation can result in substantial performance increases, as can PETTLEP imagery alone.
446 As such, applied practitioners working with athletes and exercisers to improve strength
447 performance are encouraged to use PETTLEP-based imagery interventions to contribute
448 towards improvements in strength, and practitioners should be aware that use of a video-based
449 observational aid alongside the imagery might assist in this process. This may be particularly
450 helpful when delivering imagery interventions with individuals with low imagery ability. A
451 randomized controlled trial comparing the effectiveness of PETTLEP with and without action
452 observation would be a very useful addition to the imagery and strength literature.

453 These findings also illustrate the large interindividual variations in the effects of
454 imagery and observation interventions, emphasizing the importance of practitioners carefully
455 considering individual differences in response to these. Imagery was very effective for all
456 participants, but although action observation was less consistently so, participant 2 and 4's
457 effect size data suggest considerable improvement from the addition of this to the imagery
458 intervention. Therefore, trying to implement interventions based on the results of group-based
459 studies can be problematic, and we would strongly recommend treating the results of such
460 studies with caution when implementing imagery interventions, assessing carefully the
461 individual's responses. In addition, action observation should not be an automatic addition to
462 imagery interventions as for some individuals it does not seem to add to imagery's
463 effectiveness. However, if the individual has a preference to use an observational aid to
464 accompany their imagery then the inclusion of an observational aid will not be detrimental to
465 the efficacy of the intervention.

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615 **Tables and Figures**

616 **Table 1 – Order and timing of interventions, and MIQ-3 scores**

617 **Figure 1 – Example of the internal, visual perspective used in the videos**

618 **Figure 2 – Bicep curl 1 R.M. scores for Participant 1**

619 **Figure 3 – Bicep curl 1 R.M. scores for Participant 2**

620 Figure 4 – Bicep curl 1 R.M. scores for Participant 3

621 Figure 5 – Bicep curl 1 R.M. scores for Participant 4

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	Participant 1	Participant 2	Participant 3	Participant 4
3 weeks	Baseline	Baseline	Baseline	Baseline
4 weeks	Imagery plus Video	Imagery	Imagery plus Video	Imagery
4 weeks	Imagery	Imagery plus Video	Imagery	Imagery plus Video
MIQ-3 Internal	6	6.75	6.5	4
MIQ-3 External	6.25	6.75	6.75	5
MIQ-3 Kinaesthetic	6.25	6.5	4.75	3.75

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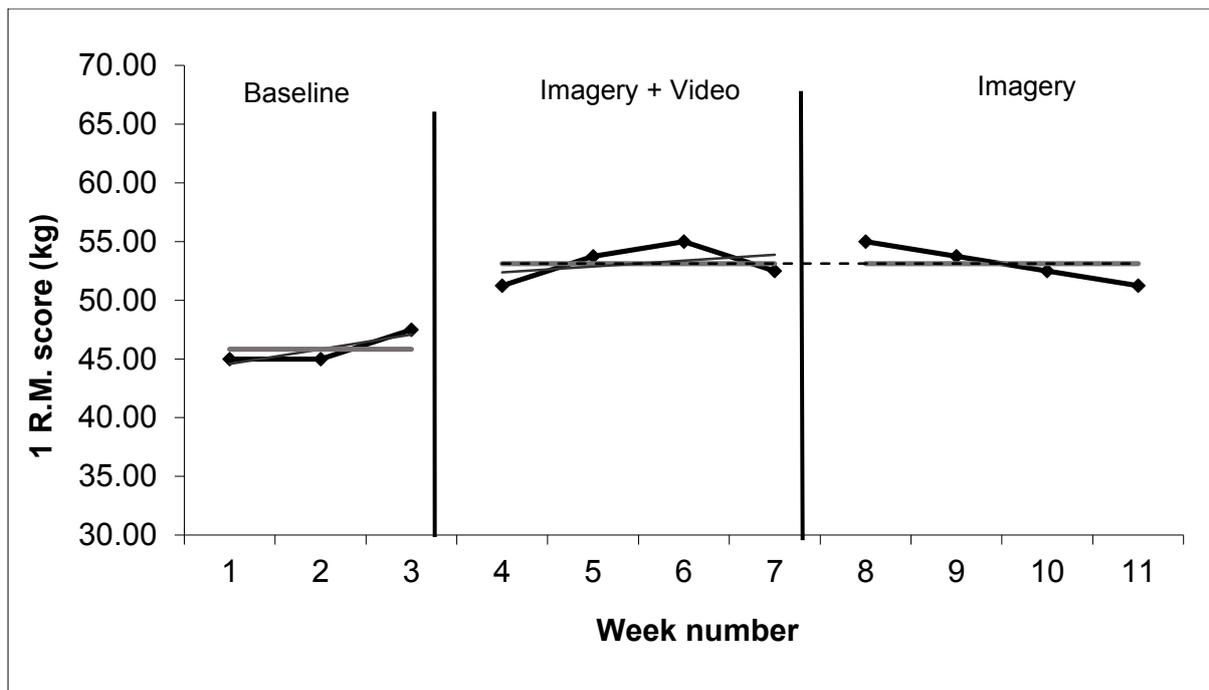
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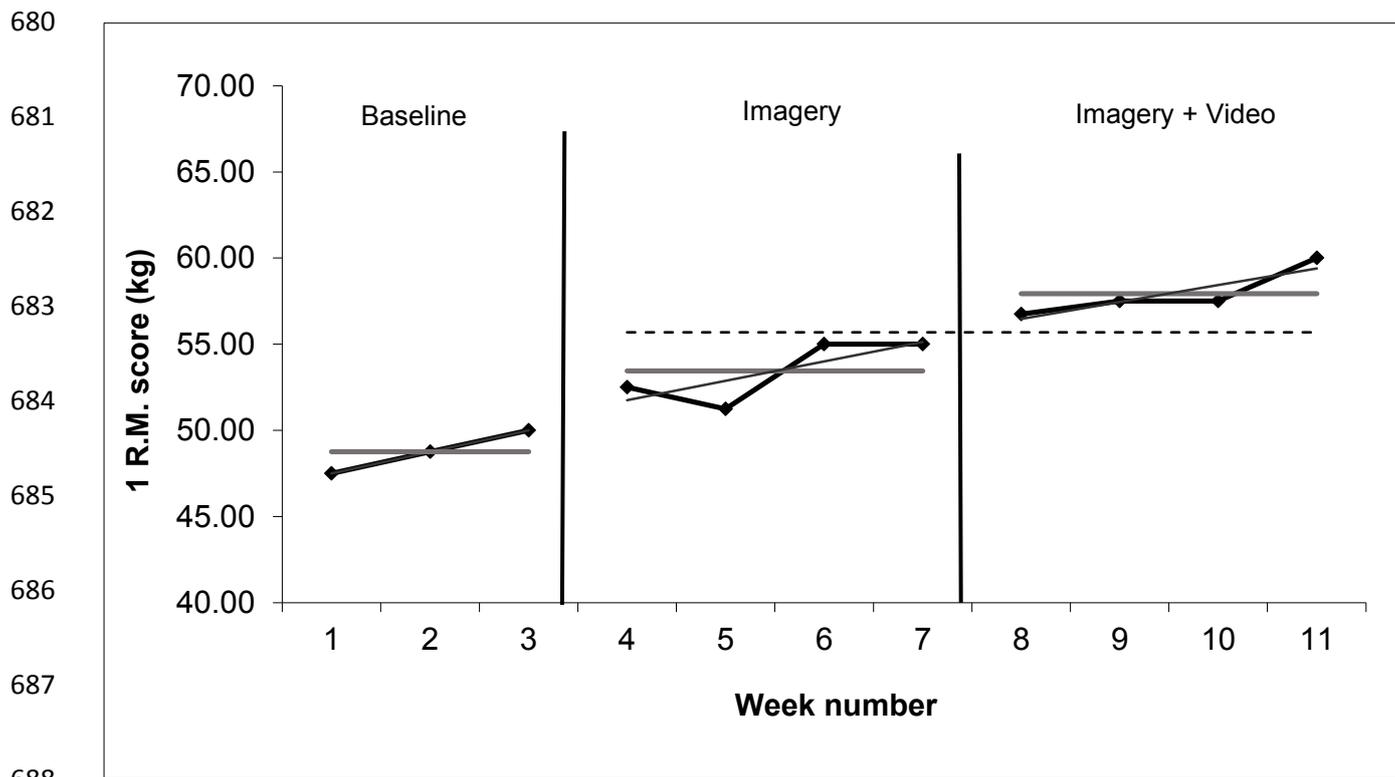
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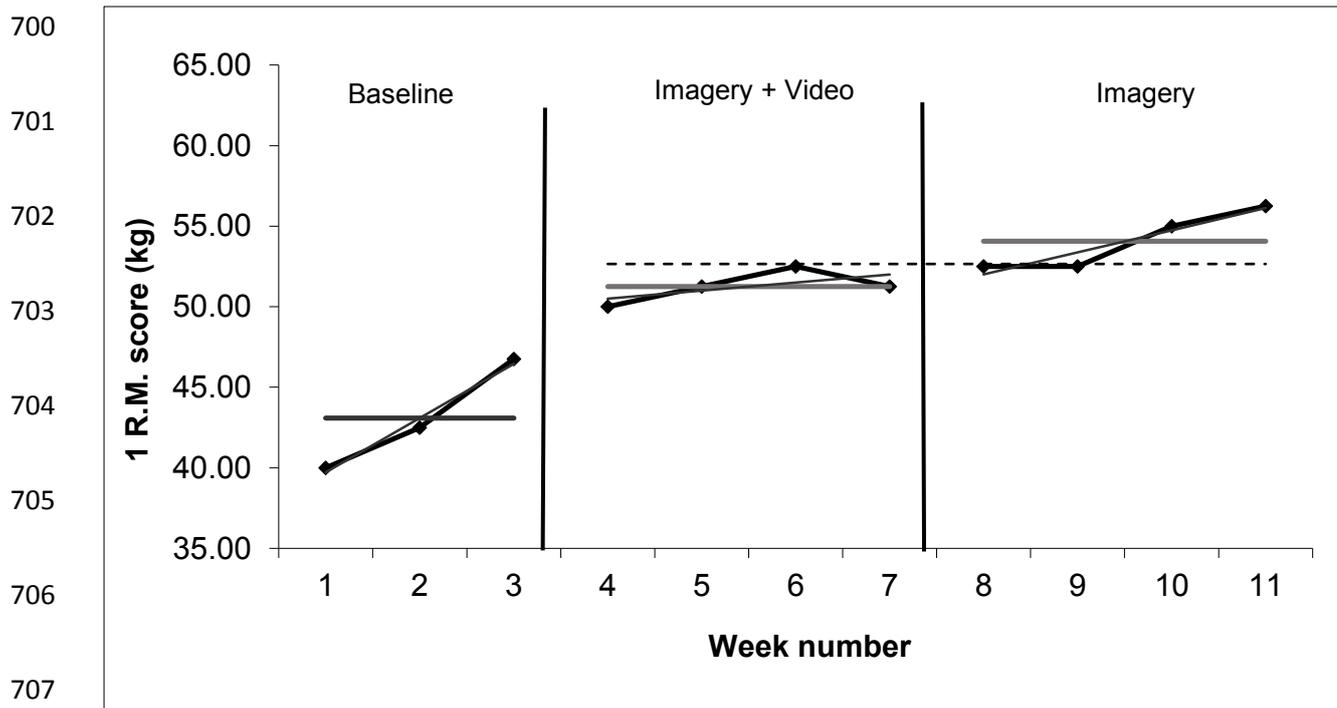
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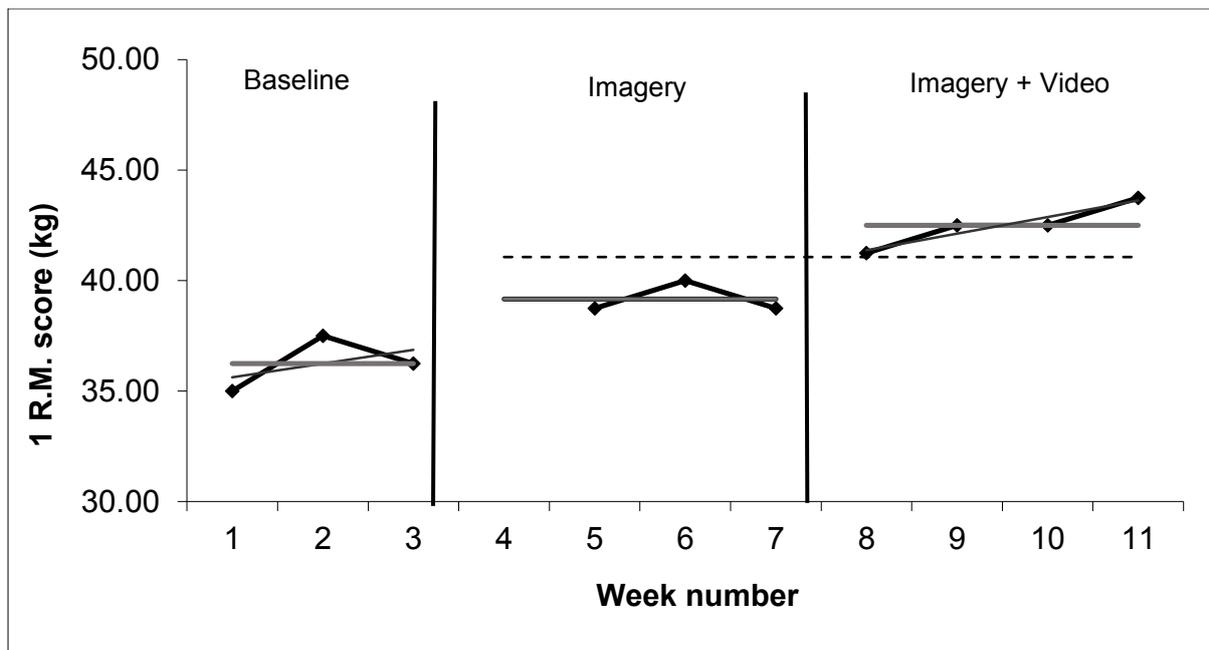
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