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Pressure Training for Performance Domains: A Meta-Analysis

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Abstract

Studies have tested pressure training (PT) interventions in which performers practice physical or technical skills under simulated psychological pressure, but research has not yet synthesized the results of these studies. This meta-analysis assessed the magnitude of PT's effect on performance in sport and other high-pressure domains (e.g., law enforcement). A secondary purpose was to investigate how domain, dose, experience, and the type of task moderated the effectiveness of interventions. A study was included if it was peer-reviewed, conducted a PT intervention for sport or another high-pressure domain, and quantitatively compared a PT group to a control group on posttests under pressure. Fourteen studies in sport ($k = 10$) and law enforcement ($k = 4$) were included. Participants ($n = 394$) were novices, semi-professional athletes, elite athletes, and police officers. After removal of an outlier, the mean effect was medium ($g = 0.67$, 95% CI [0.43, 1.12]) with low heterogeneity ($I^2 = 17.1\%$). Subgroup analysis did not indicate clear moderators of performance but did reinforce that PT can benefit both novice and experienced participants on open and closed tasks across different domains. The results suggest coaches and instructors should create pressurized training environments rather than relying on greater amounts of training to help performers adjust to pressure. Future research should develop practical pressure manipulations, conduct retention tests, and measure performance in competitive or real-life scenarios.

Keywords: stress inoculation, stress exposure, sport, law enforcement, performance under pressure, meta-analysis, systematic review

47 Pressure Training for Performance Domains: A Meta-Analysis

48 The adages “practice how you play” or “train as you fight” demonstrate that domains
49 such as sport and military understand that training should replicate performance as closely as
50 possible to improve performance. Defined as “any factors or combination of factors that
51 increase the importance of performing well on a particular occasion” (Baumeister, 1984, p.
52 610), psychological pressure is inherent to sport and other high-pressure domains, such as
53 law enforcement (Hanton, Fletcher, & Coughlan, 2005; Nieuwenhuys & Oudejans, 2011).
54 Research has studied whether training under pressure improves performance under pressure
55 (e.g., Bell, Hardy, & Beattie, 2013). This pressure training (PT) is based on stress inoculation
56 training (Meichenbaum, 2007) and involves physically practicing domain-specific skills
57 under simulated pressure. Studies have also called PT “anxiety training” (e.g., Oudejans &
58 Pijpers, 2009), “acclimatization training” (e.g., Beseler, Mesagno, Young, & Harvey, 2016),
59 and “self-consciousness training” (e.g., Beilock & Carr, 2001). Despite their different names,
60 these interventions all attempted to increase perceived pressure in training to enable
61 participants to maintain or even improve performance under pressure.

62 PT can manipulate pressure by increasing either demands or consequences of a
63 participant’s performance; however, delivering consequences seems to have a stronger effect
64 upon anxiety than increasing demands does (Stoker et al., 2017). In sport, athletes can face
65 loss of playing time, negative press, crowd derision or other consequences if they perform
66 poorly. To simulate the pressure of these consequences, interventions have added monetary
67 rewards (e.g., Oudejans & Pijpers, 2010), punishments (e.g., Bell et al., 2013), and perceived
68 evaluation by coaches (e.g., Beseler et al., 2016). In other high-pressure domains, PT
69 consequences can be inherent to the task and felt immediately (e.g., an antagonist firing back
70 at police; Nieuwenhuys & Oudejans, 2011). PT may not perfectly replicate competition or

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71 life-threatening scenarios, but evidence suggests that anxiety in training can still help even if
72 it is less severe than the anxiety felt during actual performance (Oudejans & Pijpers, 2010).

73 PT is distinct from other training methods that also manipulate conditions to prepare
74 athletes and professionals for performance. For example, in a constraints-led approach to
75 skill acquisition (Davids, Button, & Bennett, 2008), a soccer coach might train players' ball
76 control by limiting the number of touches each player can take at a time. Like PT, this
77 approach simulates performance conditions because players may not have the luxury of
78 taking several touches in competition. However, PT and a constraints-led approach improve
79 performance through different avenues: A constraints-led approach develops technical skills
80 whereas PT trains the ability to cope with psychological pressure while performing those
81 skills. Headrick, Renshaw, Davids, Pinder, and Araújo (2015) have acknowledged that
82 training would better represent performance by incorporating emotional constraints
83 experienced when performing. Pressure is one such constraint, and it can influence
84 achievement in sport and safety in domains including medicine and law enforcement (Hardy
85 et al., 2017; Arora et al., 2009; Vickers & Lewinski, 2012).

86 Although PT does not strictly teach physical or technical skills, it must combine the
87 exposure to pressure with the simultaneous practice of such skills. For example, Oudejans
88 and Pijpers (2009) found that dart players who practiced under pressure maintained
89 subsequent performance in a pressurized posttest whereas performance declined for players
90 who were merely exposed to pressure. PT does not just train the ability to cope with anxiety;
91 instead, it trains the ability to cope while simultaneously executing skills or making
92 decisions. PT is not necessarily a separate exercise from a performer's normal training
93 regimen because a coach or instructor can increase pressure during an already-scheduled
94 exercise. For instance, if a basketball team already practices free throws, then practicing free

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95 throws under pressure does not necessarily take much more time. Therefore, PT enhances
96 existing training rather than introducing a completely new and unfamiliar exercise.

97 Systematic reviews have supported the effectiveness of PT (Gröpel & Mesagno, 2017;
98 Kent, Devonport, Lane, Nicholls, & Friesen, 2018). In Kent et al. (2018), all five PT or
99 “simulation training” interventions improved performance under pressure whereas all other
100 interventions, such as cognitive-behavioral workshops and emotional regulation strategies,
101 produced mixed results. In Gröpel and Mesagno’s (2017) systematic review of choking
102 interventions, eight out of nine PT studies (“acclimatisation training” or “self-consciousness
103 training”) led to statistically significant improvements in performance under pressure. Even
104 though these findings are promising, they do not illustrate the magnitude of PT’s effect on
105 performance. Kent et al. (2018) acknowledged that a meta-analysis would have been
106 inappropriate in their review because the variety of interventions and populations produced
107 significant heterogeneity. Similarly, the mix of interventions in Gröpel and Mesagno (2017)
108 may have also precluded meta-analysis. A review focused exclusively on PT interventions
109 could have enough homogeneity to quantify their effect.

110 Comparing Kent et al. (2018) and Gröpel and Mesagno (2017) also reveals a need to
111 more thoroughly assess PT research. These two reviews included only one of the same PT
112 studies (i.e., Bell et al., 2013), and relevant literature could also include research on domains
113 other than sport. Law enforcement and other domains inherently operate under pressure and
114 already simulate their operating environments in training (e.g., Saus, Johnsen, Eid, Andersen,
115 & Thayer, 2006). Systematic reviews in these domains have examined training of non-
116 technical skills, such as teamwork (O’Dea, O’Connor, & Keogh, 2014), but no study has
117 reviewed training for the domains’ psychological pressures.

118 Sport does not have the same life-or-death risks associated with law enforcement,
119 medicine, or aviation, but all of these domains require coping with pressure and have already

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120 learned from each other to improve training (Arora et al., 2009; Hanton et al., 2005).
121 Medicine has adopted aviation's crew resource management training (Hamman, 2004; O'Dea
122 et al., 2014) as well as athletes' cognitive training techniques, such as mental imagery
123 (Wallace et al., 2017). Sport psychology has also informed military training (e.g., Fitzwater,
124 Arthur, & Hardy, 2018). Despite the prevalence of pressure and the interest in improving
125 training, little research has compared how these domains create and train in pressurized
126 environments.

127 Even if PT has unique effects in sport compared to other domains, any differences
128 could highlight the potential for learning across domains. Some heterogeneity is to be
129 expected in a meta-analysis because included studies rarely all use the same methods and
130 study the same participants (Higgins, 2008), and such heterogeneity would be expected
131 especially for PT because these interventions can vary on several characteristics. Dose, or the
132 number of PT sessions, has ranged from a single session (e.g., Beilock & Carr, 2001) to
133 multiple sessions per week for several months (e.g., Bell et al., 2013). PT has been examined
134 in novices and professionals (e.g., Liu, Mao, Zhao, & Huang, 2018; Oudejans, 2008), and PT
135 can train performance of closed or open tasks under pressure (e.g., Alder, Ford, Causer, &
136 Williams, 2016; Lewis & Linder, 1997). In closed tasks (e.g., golf putting), the performer
137 chooses when to start executing a skill. In open tasks, the performer must execute a skill in
138 response to a changing environment. Hitting a groundstroke in tennis is an open skill because
139 the player must respond to the speed and location of an opponent's shot. Reviewing PT
140 research could identify characteristics of PT associated with certain domains. Subgroup
141 analysis could then quantify whether these characteristics moderated PT's effect, and results
142 could provide rationale for one domain to adopt the best practices of another.

143 Findings of such a review could illustrate PT's value relative to other interventions
144 and guide the timing, context, and design of PT. From a theoretical perspective, this

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145 synthesis could support or challenge potential explanations for PT's effects. Therefore, the
146 current study's purpose was to assess the magnitude of PT's effect on performance under
147 pressure in sport and other high-pressure domains. PT was defined as physically practicing
148 domain-specific skills under simulated pressure. A secondary purpose was to explore if and
149 how domain, dose, task type, and experience each moderated PT's effect.

150 **Method**

151 **Literature Search**

152 The method of this review followed PRISMA guidelines. Search terms were based on
153 titles and keywords of PT studies already known to the authors, and six Boolean
154 combinations were used to search MEDLINE, PsycINFO, PsycARTICLES, and
155 SPORTDiscus. These databases were searched together in one search of EBSCOHost in
156 August 2019. Boolean combinations were: 1) "pressure training" OR "practice with anxiety"
157 OR "acclimatization training" OR "resilience training", 2) performance under pressure AND
158 sport AND training, 3) "practice under pressure" OR "performance under pressure" OR
159 "anxiety training" OR "acclimatization training," 4) performance under pressure AND
160 anxiety AND training, 5) (simulation training or simulation education or simulation learning)
161 AND anxiety, and 6) ("stress exposure training" or "stress inoculation training" or "stress
162 training") AND performance. Searches were limited to scholarly journals, and they were not
163 limited to any particular dates because this review was the first to examine PT exclusively.

164 Figure 1 illustrates the search and sifting process. The first and fourth authors
165 independently sifted the search results by title and abstract, compared results, and resolved
166 disagreements through discussion. Full text was examined when titles and abstracts were
167 insufficient to determine eligibility. The first author also conducted backward and forward
168 reference searching of studies after the final set of included studies from the search was
169 determined. For the backward search, reference lists of these studies were scanned for other

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170 eligible studies. For the forward search, the “cited by” functions in the databases SCOPUS,
171 Web of Science, and Google Scholar were used to identify articles that have since cited any
172 of the already-included studies. Results were sifted by title, abstract, and full.

173 **Inclusion Criteria**

174 Studies were included if they: 1) trained and tested individuals on domain-specific
175 skills, 2) conducted an intervention in which participants physically trained under simulated
176 pressure, 3) compared an experimental group with a control group in a randomized or non-
177 randomized study, 4) quantitatively measured each group’s performance outcomes in a high-
178 pressure posttest, 5) were written in English, and 6) were peer-reviewed and empirical.

179 Inclusion was not limited to participants’ level of experience because subgroup analysis was
180 determined *a priori* to analyze level of experience. The fourth criterion specified
181 performance in posttests because few sport psychology studies have measured performance
182 in actual competition or real-life scenarios (Martin, Vause, & Schwartzman, 2005).

183 **Data Items and Collection**

184 The following pre-determined information was collected from each included study: 1)
185 experimental design, 2) total *n*, 3) domain, 4) experience, 5) task, 6) task type (open or
186 closed), 7) dose, and 8) pressure manipulations. According to the framework developed by
187 Stoker, Lindsay, Butt, Bawden, and Maynard (2016), pressure manipulations were classified
188 as forfeits (e.g., cleaning a changing room; Bell et al., 2013), rewards (e.g., money), judgment
189 (e.g., evaluation by coaches), task stressors (e.g., time to complete a task), performer stressors
190 (e.g., fatigue), or environmental stressors (e.g., noise). The first author completed a coding
191 sheet with each variable for each study, and the fourth author verified the data. Six
192 disagreements were resolved through discussion.

193 Mean posttest scores and standard deviations were extracted from articles or obtained
194 by e-mailing authors. Four authors were e-mailed, and two responded with the requested

195 data. GetData Graph Digitizer (<http://getdata-graph-digitizer.com>) was used to estimate data
196 from graphs when means could not be obtained from articles or contact with authors.
197 Standard errors and sample sizes were used to calculate standard deviations for each group
198 for studies that did not report standard deviations.

199 **Assessment of Bias**

200 Risk of bias in randomized studies was assessed using the Cochrane Collaboration's
201 tool for assessing risk of bias (Higgins & Green, 2011). For each study, the first and fourth
202 authors assessed risks of selection, performance, detection, and attrition biases as low, high,
203 or unclear. The authors evaluated non-randomized studies for the same biases using the Risk
204 of Bias Assessment tool for Nonrandomized Studies (Kim et al., 2013). Studies that did not
205 explicitly state if they were randomized were considered to be non-randomized.

206 It was anticipated that most studies would share unclear or high risks for many
207 categories of bias because psychological studies do not typically follow procedures such as
208 allocation concealment or blinding of researchers. Therefore, this assessment was intended to
209 compare the included studies with each other and identify any bias that could distinguish
210 studies within the review. For example, if risk of one bias was high in half the studies and
211 low in the other half, then that bias would warrant further analysis to see if it affected results.

212 To assess bias across studies, a funnel plot displayed each study's effect size against
213 the study's precision (i.e., standard error). Poor methodological designs or poor analysis can
214 inflate effect sizes in small studies, and publication bias may prevent publication of studies
215 with statistically non-significant results. Asymmetry in the funnel plot and a significant
216 result from Egger's test would suggest the presence of publication bias or small-study effects.

217 **Summary Measures and Planned Method of Analysis**

218 The effect of PT was measured by the standardized mean difference (Hedges' g)
219 between posttest performance scores of control and experimental groups. Each study was

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220 also inspected for differences between experimental and control groups at baseline. Hedges'
221 g was used because it corrects for bias from small samples (Lakens, 2013). Using the
222 DerSimonian and Laird approach in Stata, a random-effects model calculated an effect size
223 and 95% confidence interval for each study as well as a pooled effect size and its 95%
224 confidence interval. The heterogeneity of study characteristics supported a random-effects
225 model, which assumes that all the studies represent different, but related, interventions
226 (Higgins & Green, 2011). A random-effects model also allows inferences to generalize
227 beyond included studies whereas results of fixed-effects models only apply to included
228 studies (Field & Gillett, 2010). Effect sizes of 0.2, 0.5, and 0.8 were interpreted as small,
229 medium, and large, respectively (Cohen, 1988). I^2 was calculated to measure heterogeneity.
230 Expressed as a percentage, I^2 represents the variation across results due to heterogeneity
231 among studies rather than chance (Higgins, Thompson, Deeks, & Altman, 2003).

232 Pre-specified additional analyses tested four potential moderators of PT effectiveness:
233 domain, dose, experience, and task type. Domain referred to sport or another field (e.g.,
234 aviation, law enforcement, medicine) and was examined because differences in population,
235 technical skills, and consequences of performance might influence PT's effectiveness. Dose
236 referred to the number of PT sessions, and it was analyzed to help coaches and sport
237 psychology practitioners determine how much PT they should conduct to improve
238 performance. It would also guide future research because doses that are too short or too long
239 could confound results of otherwise well-designed PT. Participants' experience in the
240 domain being tested was examined because psychological interventions have had different
241 effects for novices and experienced performers (e.g., Feltz & Landers, 1983). Many sports
242 and occupations involve a mix of open and closed tasks, so task type was examined because
243 the applicability of PT to each domain may depend on whether PT can improve performance

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244 on either type of task. A pooled Hedges' g , 95% confidence interval, and I^2 were calculated
245 for each subgroup.

246 Five special circumstances required processing data to make them suitable for the
247 meta-analysis. First, some performance measures (e.g., mean radial distance in golf putting;
248 Beilock & Carr, 2001) were reversed so that greater values represented better performance,
249 which aligned with measures in the other studies. Second, only two groups were compared
250 even if a study had more than two groups (e.g., control, low-anxiety training, and high-
251 anxiety training; Lawrence et al., 2014). Groups that physically trained under low pressure
252 were used as the control group, instead of groups that did not train at all. Third, measures
253 were averaged when a study had multiple continuous measures of performance (Bell et al.,
254 2013). Fourth, performance was compared on posttests, rather than retention tests, because
255 only one study conducted a retention test (Nieuwenhuys & Oudejans, 2011). Posttests
256 assessed the effects of PT immediately after the intervention whereas a retention test would
257 take place weeks or months after the intervention to assess how long effects were sustained.
258 Finally, for studies that tested participants under low and high pressure (e.g., Oudejans &
259 Pijpers, 2009), only scores from high-pressure posttests were used to calculate effect sizes.

260

Results

261 A total of fourteen studies were included in the meta-analysis. Ten studies were
262 found in the database search. Four studies were found via backward searching. Zero studies
263 were found via forward searching. Interrater agreement was 89% after reviewing titles, 97%
264 after reviewing abstracts, and 92% after reviewing full texts. Case studies did not meet all
265 inclusion criteria, but some case studies provided additional examples of PT interventions
266 (Mace & Carroll, 1986; Mace, Eastman, & Carroll, 1986).

Study Characteristics

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268 Table 1 illustrates characteristics of the included studies. Ten examined sport, and
269 four examined law enforcement. Studies in any high-pressure domain were eligible for
270 inclusion, but sport and law enforcement were the only ones with studies that met all the
271 inclusion criteria. The included studies had a total of 394 participants and mean sample size
272 of 28 participants ($SD = 20$). Participants were novices, trainees, semi-professionals,
273 professionals, and international-level athletes. Doses ranged from 1 to 46 sessions of PT.
274 Some studies used multiple pressure manipulations, and other studies used only one.
275 Judgment was the most common ($k = 8$), followed by rewards ($k = 6$) and forfeits ($k = 4$).

276 **Risk of Bias**

277 Table 2 illustrates the results of the bias assessments. No single type of within-study
278 bias distinguished studies into subgroups because there was little variation in their ratings on
279 each category. Interrater agreement was 86%. A relatively symmetrical funnel plot and a
280 non-significant Egger's test result ($P = 0.12$) showed no indication of significant publication
281 bias or small-study effects across studies.

282 **Mean Effect**

283 The forest plot in Figure 2 presents the individual and pooled effect sizes, 95%
284 confidence intervals, and the weight of each study. Across the included studies, PT had a
285 large positive effect on performance under pressure for experimental groups when compared
286 to control groups that did not receive PT ($g = 0.85$, 95% CI [0.37, 1.34]). Only Bell et al.
287 (2013) had a significant difference between experimental and control groups at baseline on
288 one performance measure, and this difference was balanced by no significant difference
289 between groups on a second measure. Heterogeneity between studies was high ($I^2 = 78.4\%$).

290 The forest plot showed that one study (Liu et al., 2018) could be responsible for much
291 of the high heterogeneity, so sensitivity analysis was conducted to measure the influence of
292 each study on the mean effect. The mean effect was re-calculated while omitting each study

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293 one at a time. Omission of Liu et al. (2018) decreased Hedges' g from 0.85 to 0.67 and the
294 upper limit of the 95% confidence interval from 1.33 to 0.94. In contrast, when any other
295 study was omitted, Hedges' g was at least 0.83, and the upper limit of the 95% confidence
296 interval was at least 1.34. Omission of Liu et al. (2018) also decreased I^2 from 78.4% to
297 17.1%. This more conservative estimate indicates a medium effect with a more precise 95%
298 confidence interval ([0.41,0.94]).

299 Because of Liu et al. (2018)'s disproportional influence, it was omitted from the
300 preplanned subgroup analyses. When heterogeneity is due to study characteristics, subgroup
301 analysis can identify which characteristics are responsible, but high heterogeneity due to a
302 single study would make results of subgroup analysis difficult to interpret. Thus, this
303 omission made subgroup analysis of the remaining studies more robust.

304 **Subgroup Analysis**

305 Table 3 summarizes the effects of PT in each subgroup for the preplanned moderator
306 variables: domain, dose, task type, and experience. Domain was coded as either "sport" or
307 "law enforcement." Dose was coded as "short" (one PT session), "medium" (2-5 sessions), or
308 "long" (over five sessions). Task type was either "open" or "closed." For experience,
309 participants were divided into "novice" or "experienced" subgroups. All but one subgroup
310 (long-dose interventions) had moderate effects, so none of these variables significantly
311 moderated performance under pressure. For each variable, one subgroup's confidence
312 interval encompassed the entire confidence interval of the other subgroup(s). This overlap
313 suggests that little difference, if any, existed between PT's effects among subgroups.
314 However, heterogeneity did distinguish subgroups and warrants interpreting similarities in
315 effect size with caution. Long-dose interventions had the smallest effect of any subgroup (g
316 = 0.42, 95% CI [-0.65, 1.50]) but also had the fewest studies ($k = 3$) and the highest
317 heterogeneity ($I^2 = 73.1%$). Although heterogeneity was only moderate among experienced

318 participants ($I^2 = 48.9\%$), it was lower for novices ($I^2 = 0.0\%$). It should also be noted that all
319 studies with novices overlapped with short-dose interventions.

320 **Discussion**

321 The main purpose of this meta-analysis was to assess the effectiveness of PT for
322 enhancing performance under pressure. A secondary purpose was to explore if and how
323 domain, dose, task type, and experience each moderated the magnitude and direction of PT's
324 effect. Fourteen studies were included. Although studies from any high-pressure domain
325 were eligible for inclusion, sport and law enforcement were the only domains represented.
326 The range of the law enforcement studies was narrow: They all trained shooting skills, and
327 three of the four studies were conducted by the same authors (Nieuwenhuys & Oudejans,
328 2011; Nieuwenhuys, Savelsbergh, & Oudejans, 2015; Oudejans, 2008). Studies have
329 examined PT in firefighting and medicine (e.g., Baumann, Gohm, & Bonner, 2011; DeMaria
330 et al., 2010), but they did not meet all inclusion criteria.

331 Results supported previous systematic reviews that found PT interventions
332 consistently improved performance under pressure (Gröpel & Mesagno, 2017; Kent et al.,
333 2018). Both previous reviews compared PT with other choking or coping interventions, but
334 their reliance on statistical significance limited conclusions. Meta-analysis allowed the
335 current review to measure the magnitude of PT's effect on performance under pressure. The
336 included studies had a large positive effect ($g = 0.85$, 95% CI [0.37, 1.34]). This effect
337 represents between-group differences on high-pressure posttests, so it suggests that
338 performers who receive PT outperform others who do not receive PT. It does not, however,
339 describe how that performance under high pressure compares to performance under low
340 pressure. Included studies whose effect sizes were similar to this overall effect more
341 concretely illustrate the meaning of the result. In Lawrence et al.'s (2014) experiment 1, the
342 experimental group made more than 2.5 more putts than the control group did out of 25 total

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343 putts. In Nieuwenhuys and Oudejans (2011), police officers who received PT were 14
344 percent more accurate firing at an opponent than the control group was in the posttest.

345 After removal of an outlier with an especially large positive effect (Liu et al., 2018),
346 the overall effect of PT was moderate ($g = 0.67$, 95% CI [0.41, 0.94]). Differences between
347 the SWAT trainees in Liu et al. (2018) and novices in other studies could explain the large
348 effect size. For example, the trainees may have been more motivated than other novices
349 because the task was related to the trainees' careers.

350 This medium effect of PT approximated the effects of other interventions for
351 performance enhancement. It is within the 95% confidence interval of 0.22–0.92 (Hedges' g)
352 that Brown and Fletcher (2017) found in their meta-analysis of various psychological and
353 psychosocial interventions in sport, including pre-performance routines, self-talk, and
354 imagery. Rather than competing with these interventions, PT may complement them in
355 applied practice because PT could provide a more ecologically valid setting to practice
356 routines, attentional training, or other techniques used during performance.

357 Bell et al. (2013) found PT was effective when combined with mental skills training;
358 however, the remaining studies suggested PT alone can improve performance. According to
359 Nieuwenhuys and Oudejans' (2017) model, pressure can prompt performers to increase
360 mental effort as they become more concerned with performing well, and PT may train
361 performers to direct this effort to completing their task rather than worrying about the
362 pressure. Oudejans and Pijpers (2009) found that their control and experimental groups both
363 increased effort in posttests under anxiety, but only the experimental groups' efforts
364 improved performance. The two groups both remained anxious in posttests. Thus, rather
365 than reducing anxiety, PT appeared to acclimatize participants to performing with anxiety.

366 PT effects were also consistent across domains. Police and athletes both performed
367 better under pressure after PT. They did test under the same pressure manipulations used in

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368 their PT rather than real-life or competitive pressures (e.g., “soap” bullets instead of real
369 bullets), which warrants more research to examine how well PT would translate to
370 competition or an encounter with a suspect. The differences between control and
371 experimental groups do imply that pressure can limit performance, so the results at least
372 highlight the need to prepare for such pressure in both domains. One difference between the
373 domains is that all police studies trained open tasks whereas most sport studies trained closed
374 tasks. The open tasks were “extended” in that they involved a continuous series of
375 opportunities to perform skills (e.g., firing multiple shots, reloading the weapon, and moving
376 after each shot; Nieuwenhuys & Oudejans, 2011). Because many sports involve mostly
377 extended open-task sequences, training these tasks in PT could prepare athletes for a wider
378 variety of situations and train the ability to sustain that performance throughout a sequence.

379 Novices and experts both improved moderately after PT. The positive effect on
380 experienced participants demonstrated that performers who are physically or technically
381 skilled could still improve under pressure. Experience in one’s domain does not guarantee
382 quality performance under pressure (e.g., Alder et al., 2016). For novices, improvements
383 could be explained by the specificity of practice hypothesis, which suggests individuals
384 perform better when they have learned under the same conditions in which they perform
385 (e.g., high pressure; Cassell, Beattie, & Lawrence, 2018).

386 Interventions with five or more PT sessions had the smallest effect on performance
387 under pressure. This finding contrasts recommendations in sport psychology for consistent,
388 long-term interventions (Fifer, Henschen, Gould, & Ravizza, 2008), but the small number of
389 these studies and their varied results (Table 3) show that more studies are needed to
390 determine appropriate amounts of PT. Furthermore, we can speculate that results could differ
391 if they were measured on retention tests because the advantage of long interventions could be
392 in sustaining performance under pressure throughout a competitive season or career. Many

393 of the scenarios simulated in PT studies (e.g., game-winning free throws) may only occur
394 occasionally and unpredictably for each individual performer, so he or she may need to train
395 under pressure consistently to stay prepared for such scenarios when they do occur.

396 **Applied Implications**

397 Because control groups physically practiced as much as experimental groups did, the
398 between-group differences in performance should encourage leaders to increase pressure in
399 practice, not just the amount of practice. Challenges help individuals develop psychological
400 skills, and “constructed challenges,” such as PT, develop these skills more intentionally than
401 waiting for opportunities to occur naturally (Collins, Macnamara, & McCarthy, 2016, p.3).
402 PT also contrasts approaches to learning that center around leaders or practitioners providing
403 verbal explanations or demonstrations. While Bell et al. (2013) complemented PT with
404 mental skills training, the remaining studies suggested that a practitioner would not have to
405 explicitly teach mental skills for participants to acclimatize to pressure during PT. That is,
406 participants seemed to adapt to pressure on their own. When preparing performers for
407 pressure, leaders can create a pressurized atmosphere in which performers can independently
408 learn to perform. This PT should take place in a facilitative environment in which leaders
409 balance the challenge of pressure with support, such as strong coach-athlete relationships and
410 encouragement to learn from mistakes (Fletcher & Sarkar, 2016).

411 Coaches or instructors could consider introducing appropriate amounts of pressure
412 early in a learner’s development. PT’s effectiveness for novices illustrates that individuals
413 might not have to master a skill before training it under pressure. Furthermore, when learners
414 train while feeling emotions of competition, they may be more engaged and also discover the
415 emotions, thoughts, and behavior that they need to perform optimally (Headrick et al., 2015).

416 Simulating such pressure may be more feasible if coaches and practitioners utilize
417 stressors inherent to the task being trained. Despite increasing anxiety successfully, sport

418 studies relied on external sources of pressure, including monetary rewards, that would be
419 impractical for coaches to replicate regularly. Police, in contrast, faced consequences that
420 were directly connected to their experimental task, such as shooting a live “hostage” (with a
421 “soap” bullet) if they missed their target (Liu et al., 2018). These tasks also took place in
422 simulated performance contexts, including realistic physical surroundings and verbal
423 communication with suspects when first encountered (Nieuwenhuys et al., 2015). Similarly,
424 situating PT in a simulated performance context could provide sources of pressure that are
425 absent when individuals train a skill isolated from the flow of competition. For example, if
426 basketball players pressure trained free throws during a practice game, or “scrimmage,”
427 during a training session, they would face stressors inherent to the scrimmage itself (e.g.,
428 failing to score easy points) as well as external stressors (e.g., judgment from coaches).

429 **Future Directions & Limitations**

430 A limitation of this review is that it did not evaluate the effectiveness of different
431 pressure manipulations. Because many studies combined multiple stressors from different
432 categories in Stoker et al.’s (2016) framework of pressure manipulations, subgroup analysis
433 of each category was not possible. Stoker et al. (2017) previously examined athletes’
434 perceptions of pressure from different manipulations, but future research should test which
435 manipulations help improve performance most. In addition, low-cost and practical
436 manipulations need to be developed so coaches and instructors can regularly implement PT.

437 A first step in developing these manipulations would be to identify high-pressure
438 situations and the sources of their pressure. Although higher pressure is often associated with
439 higher stakes, subjective appraisals of a situation as a challenge or threat can also moderate
440 the effect of pressure (Seery, 2011). Factors such as the situation’s unpredictability or
441 novelty can in turn influence appraisals (Thatcher & Day, 2008). Many studies have
442 examined sources of stress for athletes (e.g., Hanton et al., 2005), but few have examined the

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443 factors that increase pressure specifically during competition. Because leveraging other
444 factors could increase pressure without increasing the size of rewards or severity of forfeits,
445 these manipulations would make longer interventions more feasible.

446 More studies on longer interventions are needed to recommend how often to
447 implement PT. Despite the appeal of “quick fix” solutions, sport psychology practitioners
448 have emphasized that time and commitment are essential for psychological training to have
449 lasting effects (Fifer et al., 2008). Still, most studies conducted fewer than five PT sessions
450 and did not attempt to extend findings in laboratory or practice settings to competition or
451 real-life scenarios. The number of sessions varied widely among the long interventions (Bell
452 et al., 2013; Beseler et al., 2016; Oudejans & Pijpers, 2009), so it remains unclear how much
453 PT is necessary for individuals to perform consistently better under pressure. PT may work
454 by systematically desensitizing performers to pressure, which would require repeated
455 exposure rather than a single session of PT. Therefore, future studies should implement PT
456 over several weeks, months, or an entire season to determine both minimum *and* maximum
457 amounts of PT. Guidelines for maximum amounts are important to establish in case longer
458 doses diminish perceived pressure during PT. Longer studies would also provide chances to
459 investigate how mental skills training might influence the efficacy and optimal dose of PT.

460 The subgroup analysis only tested how variables moderated performance on posttests,
461 but more differences between interventions may emerge if effects are also evaluated on their
462 sustainability over time. Only one study conducted a retention test (Nieuwenhuys &
463 Oudejans, 2011), so more studies are needed to measure how long athletes remain
464 acclimatized to pressure. Such retention tests could help identify amounts of PT that generate
465 permanent learning without diminishing the effects of pressure manipulations.

466 Research could also test whether improvements under pressure transfer across skills
467 within a sport or domain. Existing studies have measured PT effectiveness by testing the

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468 same skills that were practiced during PT, so it is still unknown whether performance gains
469 illustrate a general or situation-specific ability to perform under pressure. If PT trains a
470 general ability, then training one skill (e.g., tennis serves) under pressure could enhance other
471 skills (e.g., groundstrokes) under pressure too. If it trains a skill-specific ability, then
472 performers may need to pressure train many skills to prepare for the variety of situations that
473 they could face. Transfer tests should therefore be conducted to examine how pressure-
474 trained skills compare with skills not trained under pressure.

475 To truly assess transferability and sustainability, performance should also be
476 measured in competition or real-life scenarios. Differences between practice and competition
477 limits the generalizability of findings in one setting to the other, but few studies in sport
478 psychology have assessed interventions by measuring performance in competitions (Martin et
479 al., 2005). In the current review, Bell et al. (2013) did find that their experimental group
480 outperformed the control group in competition, but they measured overall performance rather
481 than performance in pressure situations. Although training under mild anxiety has prevented
482 choking under higher anxiety in laboratory settings (Oudejans & Pijpers, 2010), studies are
483 needed to support this finding in real-life or competitive performance situations.

484 **Conclusion**

485 Meta-analysis of 14 studies found PT improved performance under pressure for a
486 wide range of participants and tasks in sport and law enforcement. The mean effect was
487 medium after an outlier was excluded. Although more research should examine the role of
488 mental skills training in enhancing PT, individuals seemed to learn independently to perform
489 under pressure when given chances to practice under pressure. Interventions varied in their
490 domain, dose, participants' experience, and task type, but no single characteristic increased or
491 decreased PT's effectiveness. More clear moderators may emerge if studies examine the
492 sustainability of PT's effect over time and transferability across domain-specific skills.

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Table 1
Characteristics of Studies Included in Meta-Analysis

Study	Design	<i>N</i>	Domain	Experience	Task	Task Type	Dose	Pressure Manipulation
Alder, Ford, Causer, and Williams (2016)	R	20	Badminton	International	Reading location of opponent serves	Open	3	Judgment
Beilock and Carr (2001): experiment 3	R	36	Golf	Novice	Putting	Closed	1	Judgment
Bell, Hardy, and Beattie (2013)	NR	41	Cricket	Elite youth	Batting against pace and batting against spin	Open	46	Forfeit
Beseler, Mesagno, Young, and Harvey (2016)	R	12	Australian football	Semi-professional	Set shots	Closed	14	Environmental, judgment, reward
Lawrence et al. (2014): experiment 1	R	16	Golf	Novice	Putting	Closed	1	Judgment, reward
Lawrence et al. (2014): experiment 2	R	16	Rock climbing	Novice	Horizontal indoor climbing	Closed	1	Judgment, reward
Lewis and Linder (1997)	NR	30	Golf	Novice	Putting	Closed	1	Judgment, reward
Liu, Mao, Zhao, and Huang (2018)	R	92	SWAT team	In training	Shooting in hostage rescue	Open	3	Environmental
Nieuwenhuys and Oudejans (2011)	R	27	Police	Experienced professionals	Handgun shooting	Open	4	Forfeit
Nieuwenhuys, Savelsbergh, and Oudejans (2015)	NR	34	Police	Experienced professionals	Shoot/don't-shoot decisions	Open	3	Forfeit
Oudejans (2008)	NR	17	Police	Experienced professionals	Handgun shooting	Open	3	Forfeit
Oudejans and Pijpers (2009): experiment 1	NR	17	Basketball	"Expert"	Free throws	Closed	9	Judgment, reward
Oudejans and Pijpers (2009): experiment 2	NR	17	Darts	"Experienced"	Dart throwing	Closed	1	Environmental
Oudejans and Pijpers (2010)	R	24	Darts	Novice	Dart throwing	Closed	1	Judgment, reward

Note. R = randomized; NR = non-randomized; *N* = total number of participants in control and experimental groups included in the meta-analysis.

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Table 2
Risk of bias assessments results

Randomized studies							
Study	Selection: randomization	Selection: allocation	Performance	Detection	Attrition	Reporting	Other
Alder et al. (2016)	Unclear	Unclear	Unclear	Unclear	Unclear	Low	Low
Beilock & Carr (2001)	Unclear	Unclear	Unclear	Unclear	Unclear	Low	High
Beseler et al. (2016)	Unclear	Unclear	High	Unclear	High	High	Low
Lawrence et al. (2014): expt. 1	Unclear	Unclear	Unclear	Unclear	Unclear	Low	High
Lawrence et al. (2014): expt. 2	Unclear	Unclear	Low	Low	Unclear	Low	High
Liu et al. (2018)	Unclear	Unclear	Unclear	Low	High	Low	Low
Nieuwenhuys & Oudejans (2011)	Unclear	Unclear	Unclear	Unclear	Unclear	Low	Low
Oudejans & Pijpers (2010)	Unclear	Unclear	Unclear	Unclear	Unclear	Low	Low
Non-randomized studies							
Study	Selection	Confounds	Measurement Exposure	Blinding	Incomplete Data	Selective Reporting	
Bell et al. (2013)	Low	Low	Low	Unclear	High	Low	
Lewis & Linder (1997)	Unclear	Unclear	Low	Low	Low	Low	
Nieuwenhuys et al. (2015)	Unclear	Unclear	Low	Low	Unclear	Low	
Oudejans (2008)	Unclear	Unclear	Low	Low	Unclear	Low	
Oudejans & Pijpers (2009): expt. 1	High	Low	Low	Low	Unclear	Low	
Oudejans & Pijpers (2009): expt. 2	Unclear	Low	Low	Low	Unclear	Low	

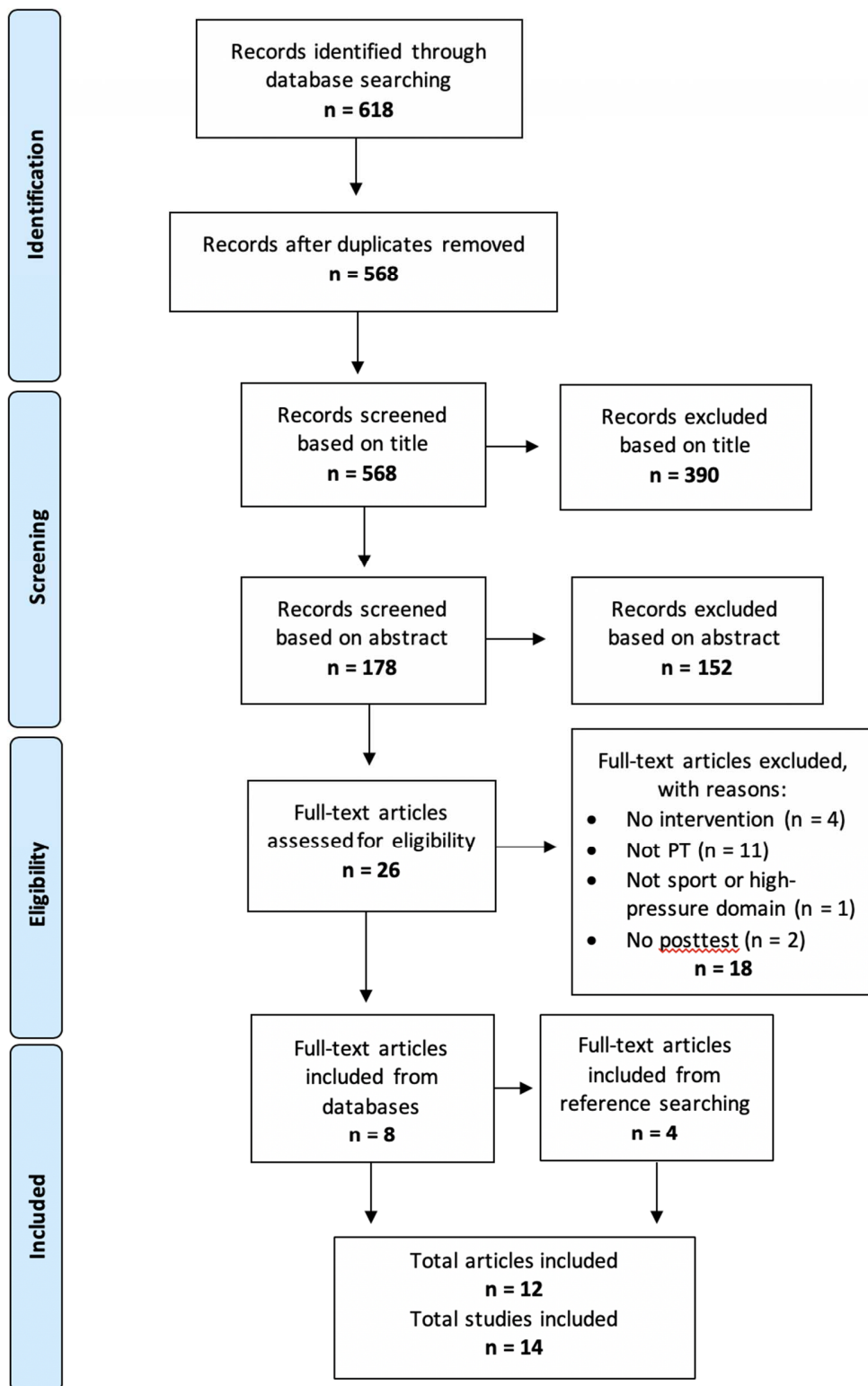
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Table 3
Effect of Moderator Variables

Moderator	Subgroup	<i>k</i>	<i>N</i>	<i>g</i>	95% CI	Effect descriptor	<i>P</i>	Within-group <i>I</i> ² (%)
Domain	Sport	10	224	0.72	[0.45, 1.00]	Moderate	< 0.001	0.0
	Law enforcement	3	78	0.63	[-0.14, 1.39]	Moderate	0.107	60.5
Experience	Experienced	8	180	0.61	[0.17, 1.05]	Moderate	0.007	48.9
	Novice	5	122	0.77	[0.40, 1.14]	Moderate	< 0.001	0.0
Dose	Short	6	139	0.73	[0.38, 1.08]	Moderate	< 0.001	0.0
	Medium	4	98	0.72	[0.11, 1.33]	Moderate	0.021	51.3
	Long	3	65	0.42	[-0.65, 1.50]	Small	0.440	73.1
Task Type	Open	5	134	0.74	[0.27, 1.20]	Moderate	0.002	38.2
	Closed	8	168	0.65	[0.30, 0.99]	Moderate	< 0.001	12.2

648 *Note.* *k* = number of studies; *N* = total number of participants; *g* = Hedges' *g*; CI = confidence interval

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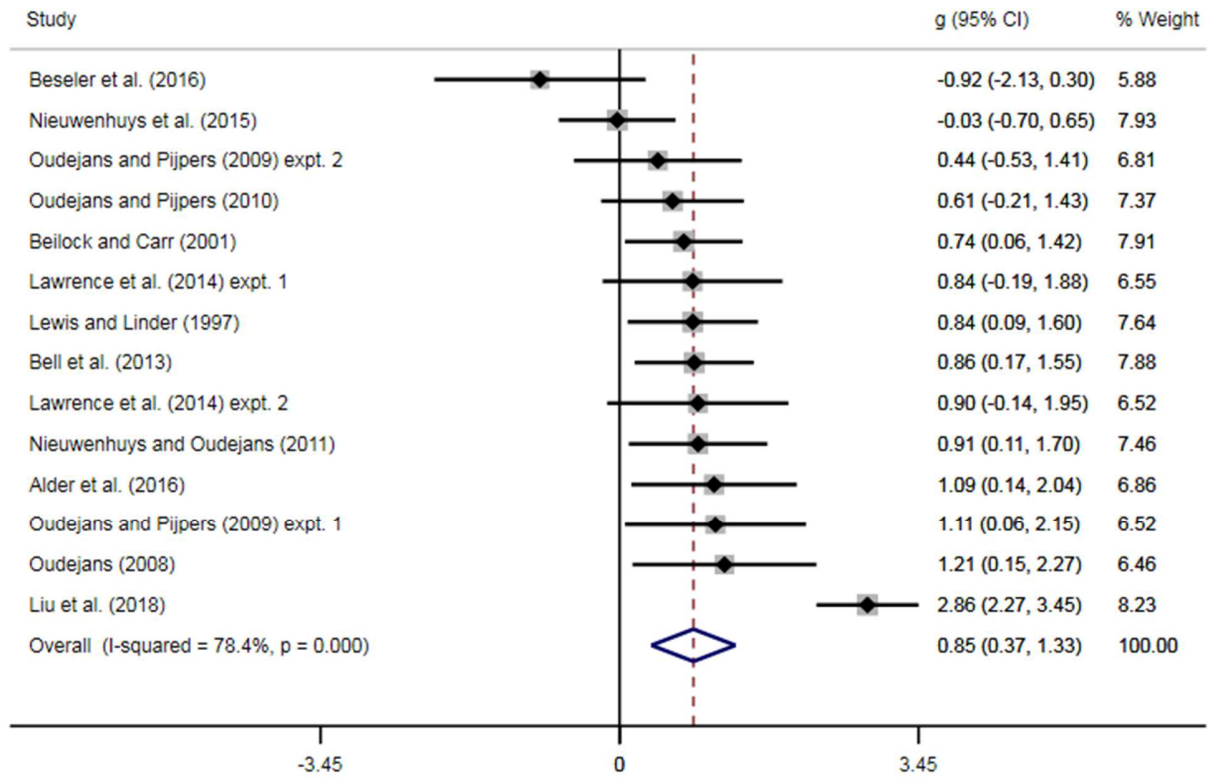


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650 Figure 1. Identification of studies included in meta-analysis.

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653 Figure 2. Forest plot of study effect sizes in ascending order.