



## LJMU Research Online

**Low, WR, SANDERCOCK, GRH, FREEMAN, P, WINTER, M, Butt, J and Maynard, I**

**Pressure Training for Performance Domains: A Meta-Analysis.**

<http://researchonline.ljmu.ac.uk/id/eprint/13094/>

### Article

**Citation** (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

**Low, WR, SANDERCOCK, GRH, FREEMAN, P, WINTER, M, Butt, J and Maynard, I (2020) Pressure Training for Performance Domains: A Meta-Analysis. Sport, Exercise, and Performance Psychology. ISSN 2157-3905**

LJMU has developed [LJMU Research Online](#) for users to access the research output of the University more effectively. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LJMU Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The version presented here may differ from the published version or from the version of the record. Please see the repository URL above for details on accessing the published version and note that access may require a subscription.

For more information please contact [researchonline@ljmu.ac.uk](mailto:researchonline@ljmu.ac.uk)

<http://researchonline.ljmu.ac.uk/>

Pressure Training for Performance Domains: A Meta-Analysis

William R. Low<sup>1</sup>, G.R.H. Sandercock<sup>1</sup>, Paul Freeman<sup>1</sup>, Marie E. Winter<sup>1</sup>, Joanne Butt<sup>2</sup>, &  
Ian Maynard<sup>1</sup>

<sup>1</sup> University of Essex, UK

<sup>2</sup> Sheffield Hallam University, UK

Author note:

All correspondence should be addressed to William Low, School of Sport, Rehabilitation and  
Exercise Sciences, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, United  
Kingdom. E-mail: w118596@essex.ac.uk

Funding: This research did not receive any specific grant from funding agencies in the public,  
commercial, or not-for-profit sectors.

22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44

**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

### 45 Pressure Training for Performance Domains: A Meta-Analysis

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

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

## PRESSURE TRAINING META-ANALYSIS

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

### 148 **Method**

#### 149 **Literature Search**

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

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

## PRESSURE TRAINING META-ANALYSIS

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

### 171 **Inclusion Criteria**

172 Studies were included if they: 1) trained and tested individuals on domain-specific  
173 skills, 2) conducted an intervention in which participants physically trained under simulated  
174 pressure, 3) compared an experimental group with a control group in a randomized or non-  
175 randomized study, 4) quantitatively measured each group’s performance outcomes in a high-  
176 pressure posttest, 5) were written in English, and 6) were peer-reviewed and empirical.  
177 Inclusion was not limited to participants’ level of experience because subgroup analysis was  
178 determined *a priori* to analyze level of experience. The fourth criterion specified  
179 performance in posttests because few sport psychology studies have measured performance  
180 in actual competition or real-life scenarios (Martin, Vause, & Schwartzman, 2005).

### 181 **Data Items and Collection**

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

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

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

### 197 **Assessment of Bias**

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

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

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

### 215 **Summary Measures and Planned Method of Analysis**

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

## PRESSURE TRAINING META-ANALYSIS

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

### 258 **Results**

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

### 265 **Study Characteristics**

## PRESSURE TRAINING META-ANALYSIS

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

### 274 **Risk of Bias**

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

### 280 **Mean Effect**

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

### 302 **Subgroup Analysis**

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

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

318 **Discussion**

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

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

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

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

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

#### 394 **Applied Implications**

395         Because control groups physically practiced as much as experimental groups did, the  
396 between-group differences in performance should encourage leaders to increase pressure in  
397 practice, not just the amount of practice. Challenges help individuals develop psychological  
398 skills, and “constructed challenges,” such as PT, develop these skills more intentionally than  
399 waiting for opportunities to occur naturally (Collins, Macnamara, & McCarthy, 2016, p.3).

400 PT also contrasts approaches to learning that center around leaders or practitioners providing  
401 verbal explanations or demonstrations. While Bell et al. (2013) complemented PT with  
402 mental skills training, the remaining studies suggested that a practitioner would not have to  
403 explicitly teach mental skills for participants to acclimatize to pressure during PT. That is,  
404 participants seemed to adapt to pressure on their own. When preparing performers for  
405 pressure, leaders can create a pressurized atmosphere in which performers can independently  
406 learn to perform. This PT should take place in a facilitative environment in which leaders  
407 balance the challenge of pressure with support, such as strong coach-athlete relationships and  
408 encouragement to learn from mistakes (Fletcher & Sarkar, 2016).

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

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

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

### 427 **Future Directions & Limitations**

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

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

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

## PRESSURE TRAINING META-ANALYSIS

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

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

### 482 **Conclusion**

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

## References

- 491  
492 \*Alder, D., Ford, P. R., Causer, J., & Williams, A. M. (2016). The effects of high- and low-  
493 anxiety training on the anticipation judgments of elite performers. *Journal of Sport and*  
494 *Exercise Psychology*, 38, 93–104. <https://doi.org/10.1123/jsep.2015-0145>
- 495 Arora, S., Sevdalis, N., Nestel, D., Tierney, T., Woloshynowych, M., & Kneebone, R. (2009).  
496 Managing intraoperative stress: What do surgeons want from a crisis training program?  
497 *American Journal of Surgery*, 197, 537–543. doi: 10.1016/j.amjsurg.2008.02.009
- 498 Baumann, M. R., Gohm, C. L., & Bonner, B. L. (2011). Phased training for high-reliability  
499 occupations: Live-fire exercises for civilian firefighters. *Human Factors*, 53, 548–557.  
500 <https://doi.org/10.1177/0018720811418224>
- 501 Baumeister, R. F. (1984). Choking under pressure : Self-Consciousness and paradoxical effects  
502 of incentives on skillful performance. *Journal of Personality and Social Psychology*, 46,  
503 610–620.
- 504 \*Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: What governs  
505 choking under pressure? *Journal of Experimental Psychology: General*, 130, 701–725.  
506 <https://doi.org/10.1037/0096-3445.130.4.701>
- 507 \*Bell, J. J., Hardy, L., & Beattie, S. (2013). Enhancing mental toughness and performance under  
508 pressure in elite young cricketers: A 2-year longitudinal intervention. *Sport, Exercise, and*  
509 *Performance Psychology*, 2, 281–297. <https://doi.org/10.1037/spy0000010>
- 510 \*Beseler, B., Mesagno, C., Young, W., & Harvey, J. (2016). Igniting the pressure  
511 acclimatization training debate: Contradictory pilot-study evidence from Australian  
512 football. *Journal of Sport Behavior*, 39, 22–38.
- 513 Brown, D. J., & Fletcher, D. (2017). Effects of psychological and psychosocial interventions on  
514 sport performance: A meta-analysis. *Sports Medicine*, 47, 77–99.  
515 <https://doi.org/10.1007/s40279-016-0552-7>

## PRESSURE TRAINING META-ANALYSIS

- 516 Cassell, V. E., Beattie, S. J., & Lawrence, G. P. (2018). Changing performance pressure between  
517 training and competition influences action planning because of a reduction in the efficiency  
518 of action execution. *Anxiety, Stress and Coping*, *31*, 107–120.  
519 <https://doi.org/10.1080/10615806.2017.1373389>
- 520 Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York:  
521 Lawrence Erlbaum.
- 522 Collins, D. J., Macnamara, A., & McCarthy, N. (2016). Putting the bumps in the rocky road:  
523 Optimizing the pathway to excellence. *Frontiers in Psychology*, *7*(SEP), 1–6.  
524 <https://doi.org/10.3389/fpsyg.2016.01482>
- 525 Davids, K., Button, C., & Bennett, S. (2008). *Dynamics of skill acquisition: A constraints-led*  
526 *approach*. Champaign, IL: Human Kinetics.
- 527 DeMaria, S., Bryson, E. O., Mooney, T. J., Silverstein, J. H., Reich, D. L., Bodian, C., &  
528 Levine, A. I. (2010). Adding emotional stressors to training in simulated cardiopulmonary  
529 arrest enhances participant performance. *Medical Education*, *44*, 1006–1015.  
530 <https://doi.org/10.1111/j.1365-2923.2010.03775.x>
- 531 Feltz, D. L., & Landers, D. M. (1983). The effects of mental practice on motor skill learning and  
532 performance: A meta-analysis. *Journal of Sport Psychology*, *5*, 25–57.
- 533 Field, A., & Gillett, R. (2010). How to do a meta-analysis. *British Journal of Mathematical and*  
534 *Statistical Psychology*, *63*, 665–694. <https://doi.org/10.1348/000711010X502733>
- 535 Fifer, A., Henschen, K., Gould, D., & Ravizza, K. (2008). What works when working with  
536 athletes. *Sport Psychologist*, *22*, 356–377. <https://doi.org/10.1123/tsp.22.3.356>
- 537 Fitzwater, J. P. J., Arthur, C. A., & Hardy, L. (2018). “The tough get tougher”: Mental skills  
538 training with elite military recruits. *Sport, Exercise, and Performance Psychology*, *7*, 93–  
539 107. <https://doi.org/10.1037/spy0000101>
- 540 Fletcher, D., & Sarkar, M. (2016). Mental fortitude training: An evidence-based approach to

- 541 developing psychological resilience for sustained success. *Journal of Sport Psychology in*  
 542 *Action*, 7, 135–157. <https://doi.org/10.1080/21520704.2016.1255496>
- 543 Gröpel, P., & Mesagno, C. (2017). Choking interventions in sports: A systematic review.  
 544 *International Review of Sport and Exercise Psychology*, 10, 1–26.  
 545 <https://doi.org/10.1080/1750984x.2017.1408134>
- 546 Hamman, W. R. (2004). The complexity of team training: What we have learned from aviation  
 547 and its applications to medicine. *Quality and Safety in Health Care*, 13, 72–79.  
 548 <https://doi.org/10.1136/qshc.2004.009910>
- 549 Hanton, S., Fletcher, D., & Coughlan, G. (2005). Stress in elite sport performers: A comparative  
 550 study of competitive and organizational stressors. *Journal of Sports Sciences*, 23, 1129–  
 551 1141. <https://doi.org/10.1080/02640410500131480>
- 552 Hardy, L., Barlow, M., Evans, L., Rees, T., Woodman, T., & Warr, C. (2017). Great British  
 553 medalists. In *Progress in Brain Research* (1st ed., Vol. 232, pp. 1–119). Elsevier B.V.  
 554 <https://doi.org/10.1016/bs.pbr.2017.03.004>
- 555 Headrick, J., Renshaw, I., Davids, K., Pinder, R. A., & Araújo, D. (2015). The dynamics of  
 556 expertise acquisition in sport: The role of affective learning design. *Psychology of Sport*  
 557 *and Exercise*, 16, 83–90. <https://doi.org/10.1016/j.psychsport.2014.08.006>
- 558 Higgins, J. P. T. (2008). Commentary: Heterogeneity in meta-analysis should be expected and  
 559 appropriately quantified. *International Journal of Epidemiology*, 37, 1158–1160.  
 560 <https://doi.org/10.1093/ije/dyn204>
- 561 Higgins, J. P. T., & Green, S. (Eds.). (2011). *Cochrane handbook for systematic reviews of*  
 562 *interventions* (Version 5.). The Cochrane Collaboration. Retrieved from  
 563 [www.handbook.cochrane.org](http://www.handbook.cochrane.org)
- 564 Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring  
 565 inconsistency in meta-analyses. *BMJ*, 327, 557–560. doi: 10.1136/bmj.327.7414.557

## PRESSURE TRAINING META-ANALYSIS

- 566 Kent, S., Devonport, T. J., Lane, A. M., Nicholls, W., & Friesen, A. P. (2018). The effects of  
567 coping interventions on ability to perform under pressure. *Journal of Sports Science and*  
568 *Medicine, 17*, 40–55. <https://doi.org/10.1016/j.paid.2017.06.021>
- 569 Kim, S. Y., Park, J. E., Lee, Y. J., Seo, H.-J. J., Sheen, S.-S. S., Hahn, S., ... Son, H.-J. J. (2013).  
570 Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate  
571 reliability and promising validity. *Journal of Clinical Epidemiology, 66*, 408–414.  
572 <https://doi.org/10.1016/j.jclinepi.2012.09.016>
- 573 Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A  
574 practical primer for t-tests and ANOVAs. *Frontiers in Psychology, 4*, Article 863.  
575 <https://doi.org/10.3389/fpsyg.2013.00863>
- 576 \*Lawrence, G. P., Cassell, V. E., Beattie, S., Woodman, T., Khan, M. A., Hardy, L., ...  
577 Gottwald, V. M. (2014). Practice with anxiety improves performance, but only when  
578 anxious: Evidence for the specificity of practice hypothesis. *Psychological Research, 78*,  
579 634–650. <https://doi.org/10.1007/s00426-013-0521-9>
- 580 \*Lewis, B. P., & Linder, D. E. (1997). Thinking about choking? Attentional processes and  
581 paradoxical performance. *Personality and Social Psychology Bulletin, 23*, 937–944.  
582 <https://doi.org/10.1177/0146167297239003>
- 583 \*Liu, Y., Mao, L., Zhao, Y., & Huang, Y. (2018). Impact of a simulated stress training program  
584 on the tactical shooting performance of SWAT trainees. *Research Quarterly for Exercise*  
585 *and Sport, 89*, 482–489. <https://doi.org/10.1080/02701367.2018.1526003>
- 586 Mace, R., & Carroll, D. (1986). Stress inoculation training to control anxiety in sport: two case  
587 studies in squash. *British Journal of Sports Medicine, 20*, 115–117.  
588 <https://doi.org/10.1136/bjism.20.3.115>
- 589 Mace, R., Eastman, C., & Carroll, D. (1986). Stress inoculation training: A case study in  
590 gymnastics. *British Journal of Sports Medicine, 20*, 1399–141. doi: 10.1136/bjism.20.3.139

## PRESSURE TRAINING META-ANALYSIS

- 591 Martin, G. L., Vause, T., & Schwartzman, L. (2005). Experimental studies of psychological  
592 interventions with athletes in competitions: Why so few? *Behavior Modification*, *29*, 616–  
593 641. <https://doi.org/10.1177/0145445503259394>
- 594 Meichenbaum, D. (2007). Stress inoculation training: A preventative and treatment approach. In  
595 P. M. Lehrer, R. L. Woolfolk, & W. E. Sime (Eds.), *Principles and practice of stress*  
596 *management* (3rd ed.). New York: The Guilford Press.
- 597 Nieuwenhuys, A., & Oudejans, R. R. (2017). Anxiety and performance: Perceptual-motor  
598 behavior in high-pressure contexts. *Current Opinion in Psychology*, *16*, 28–33.  
599 <https://doi.org/10.1016/j.copsyc.2017.03.019>
- 600 \*Nieuwenhuys, A., & Oudejans, R. R. D. (2011). Training with anxiety: Short-and long-term  
601 effects on police officers' shooting behavior under pressure. *Cognitive Processing*, *12*,  
602 277–288. <https://doi.org/10.1007/s10339-011-0396-x>
- 603 \*Nieuwenhuys, A., Savelsbergh, G. J. P., & Oudejans, R. R. D. (2015). Persistence of threat-  
604 induced errors in police officers' shooting decisions. *Applied Ergonomics*, *48*, 263–272.  
605 <https://doi.org/10.1016/j.apergo.2014.12.006>
- 606 O'Dea, A., O'Connor, P., & Keogh, I. (2014). A meta-analysis of the effectiveness of crew  
607 resource management training in acute care domains. *Postgraduate Medical Journal*, *90*,  
608 699–708. <https://doi.org/10.1136/postgradmedj-2014-132800>
- 609 \*Oudejans, R. R. D. (2008). Reality-based practice under pressure improves handgun shooting  
610 performance of police officers. *Ergonomics*, *51*, 261–273.  
611 <https://doi.org/10.1080/00140130701577435>
- 612 \*Oudejans, R. R. D., & Pijpers, J. R. (2009). Training with anxiety has a positive effect on  
613 expert perceptual-motor performance under pressure. *Quarterly Journal of Experimental*  
614 *Psychology*, *62*, 1631–1647. <https://doi.org/10.1080/17470210802557702>
- 615 \*Oudejans, R. R. D., & Pijpers, J. R. (2010). Training with mild anxiety may prevent choking

- 616 under higher levels of anxiety. *Psychology of Sport and Exercise*, *11*, 44–50.  
 617 <https://doi.org/10.1016/j.psychsport.2009.05.002>
- 618 Saus, E.-R., Johnsen, B. H., Eid, J., Riisem, P. K., Andersen, R., & Thayer, J. F. (2006). The  
 619 effect of brief situational awareness training in a police shooting simulator: An  
 620 experimental study and the Royal Norwegian Navy. *Military Psychology*, *18*, 3–21.  
 621 <https://doi.org/10.1016/j.chb.2012.02.009>
- 622 Seery, M. D. (2011). Challenge or threat? Cardiovascular indexes of resilience and vulnerability  
 623 to potential stress in humans. *Neuroscience and Biobehavioral Reviews*, *35*, 1603–1610.  
 624 <https://doi.org/10.1016/j.neubiorev.2011.03.003>
- 625 Stoker, M., Lindsay, P., Butt, J., Bawden, M., & Maynard, I. W. (2016). Elite coaches’  
 626 experiences of creating pressure training environments. *International Journal of Sport  
 627 Psychology*, *47*, 262–281. <https://doi.org/10.7352/IJSP2016.47.262>
- 628 Stoker, M., Maynard, I., Butt, J., Hays, K., Lindsay, P., & Adams Norenberg, D. (2017). The  
 629 effect of manipulating training demands and consequences on experiences of pressure in  
 630 elite netball. *Journal of Applied Sport Psychology*, *29*, 434–448.  
 631 <https://doi.org/10.1080/10413200.2017.1298166>
- 632 Thatcher, J., & Day, M. C. (2008). Re-appraising stress appraisals: The underlying properties of  
 633 stress in sport. *Psychology of Sport and Exercise*, *9*, 318–335.  
 634 <https://doi.org/10.1016/j.psychsport.2007.04.005>
- 635 Vickers, J. N., & Lewinski, W. (2012). Performing under pressure: Gaze control, decision  
 636 making and shooting performance of elite and rookie police officers. *Human Movement  
 637 Science*, *31*, 101–117. <https://doi.org/10.1016/j.humov.2011.04.004>
- 638 Wallace, L., Raison, N., Ghumman, F., Moran, A., Dasgupta, P., & Ahmed, K. (2017).  
 639 Cognitive training: How can it be adapted for surgical education? *Surgeon*, *15*, 231–239.  
 640 <https://doi.org/10.1016/j.surge.2016.08.003>  
 641

PRESSURE TRAINING META-ANALYSIS

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.

PRESSURE TRAINING META-ANALYSIS

643  
644  
645

Table 2  
*Risk of bias assessments results*

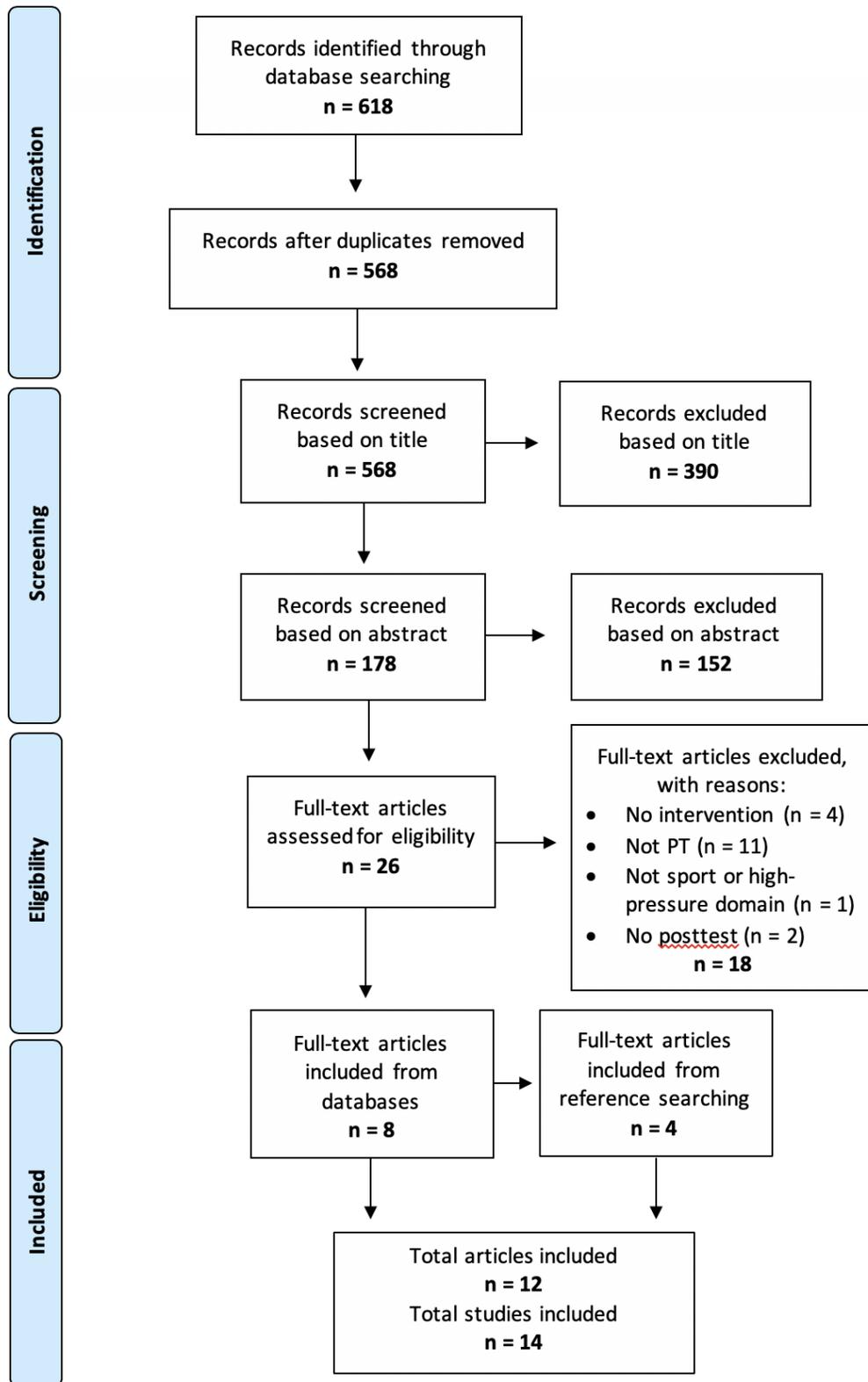
Randomized studies							
Study	Selection: randomization	Selection: allocation	Performance	Detection	Attrition	Reporting	Other
Alder et al. (2016)	Unclear	Unclear	Unclear	Unclear	Unclear	Low	Low
Beilock & Carr (2001)	Unclear	Unclear	Unclear	Unclear	Unclear	Low	High
Beseler et al. (2016)	Unclear	Unclear	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	

PRESSURE TRAINING META-ANALYSIS

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> <sup>2</sup> (%)
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

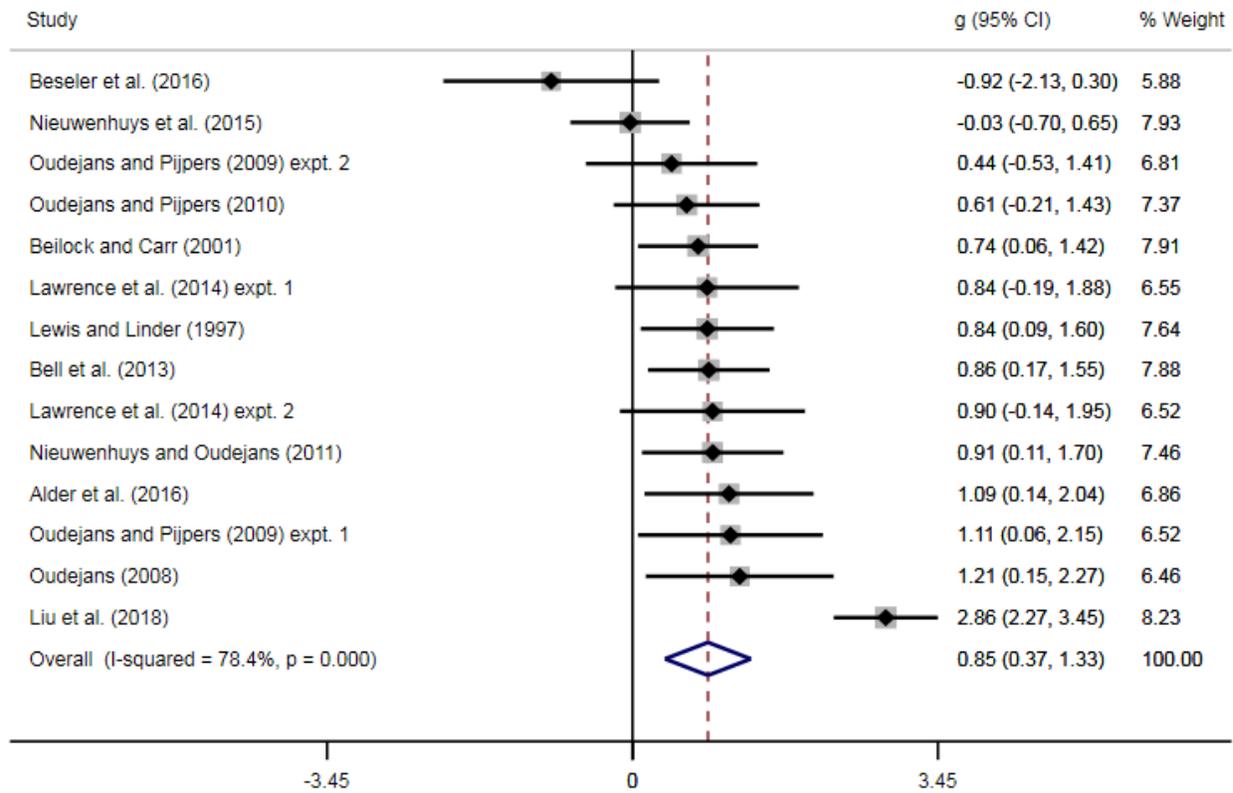
646 *Note.* *k* = number of studies; *N* = total number of participants; *g* = Hedges' *g*; CI = confidence interval



647

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

649



650

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