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Examining physical exertion as a potential cause of choking

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15 **Abstract**

16 Choking in sport is precipitated by a broad range of documented antecedents. One potential
17 antecedent that may hinder performance under pressure is physical exertion. In the current
18 experiment, a within-subjects design was implemented with 50 student-athletes who
19 completed 40 basketball free-throws in four manipulated conditions: higher pressure-running,
20 higher pressure-no running, lower pressure-running, and lower pressure-no running. A
21 repeated measures analysis of variance revealed that participants scored significantly lower in
22 the higher-pressure conditions than the lower-pressure conditions. Furthermore, participants
23 scored significantly higher in the no-running conditions compared to the running conditions.
24 The current results are in keeping with the conventional wisdom that physical effort can
25 undermine performance in pressure circumstances. The applied implications of these results
26 are discussed and tentative conclusions drawn for sport psychologists, coaches, and athletes.

27 **Keywords:** Choking, anxiety, physical exertion, basketball, free-throw shooting

28

29 **Introduction**

30 Fans witnessed a close and high standard contest in the deciding game seven of the
31 2016 National Basketball Association (NBA) championship series between the Cleveland
32 Cavaliers and the Golden State Warriors. Suddenly and inexplicably, the shooting skills of the
33 Warriors, one of the best offensive teams of NBA history, seemed to evaporate as they missed
34 eight consecutive shots in the final five minutes of the game, eventually losing the
35 championship series. Observers were left wondering what was the cause of this sudden
36 deterioration in shooting performance. Was it related to high pressure, crowd effects, fatigue
37 or possibly a combination of these factors? The phenomenon of choking was defined
38 originally as “performance decrements under pressure situations” (Baumeister, 1984, p. 610).
39 Although no single operational definition of choking is universally accepted, recently choking

40 has been defined as “heightened levels of perceived pressure and where incentives for optimal
41 performance are at a maximum lead to acute or chronic forms of suboptimal performance or
42 performing more poorly than expected given one's skill level and self-set performance
43 expectations” (Gucciardi, Longbottom, Jackson, & Dimmock, 2010, p. 79). Mesagno and Hill
44 (2013) also developed a more stringent definition; “an acute and considerable decrease in skill
45 execution and performance when self-expected standards are normally achievable, which is
46 the result of increased anxiety under perceived pressure” (p. 273).

47 Sport psychology and social psychology researchers have attempted to explain choking
48 behavior by developing and testing choking theories. In recent decades, two predominant
49 theories have emerged; the distraction theory (Carver & Scheier, 1981) and the self-focus
50 theory (Baumeister, 1984). According to proponents of distraction theories, task-irrelevant
51 thoughts, such as perceived pressure, occupy working memory and result in the athletes
52 processing the required information for skill execution alongside competing cognitions.
53 Concomitant with perceived anxiety is a type of dual-task condition for athletes, whereby
54 anxiety competes with the information required for skill execution. Consequently, attentional
55 resources are co-opted away from the execution of the primary task. This results in inefficient
56 processing of task-relevant information, and possibly choking (e.g., Beilock & DeCaro, 2007;
57 Markman, Maddox, & Worthy, 2006). Researchers have also tested and reported positively on
58 the relevance of Processing Efficiency Theory (PET; Eysenck & Calvo, 1992), a derivative
59 version of distraction theory, whereby athletes sometimes overcome inefficient processing
60 under pressure by increasing effort (Murray & Janelle, 2003; Wilson, Smith, & Holmes,
61 2007). Employing effort, however, may not be sufficient or advisable in pressure
62 circumstances, because attentional capacities may be overwhelmed by high levels of anxiety
63 (Hill, Hanton, Matthews, & Fleming, 2010; Williams, Vickers, & Rodrigues, 2001).

64 Advocates of self-focus theories have explained that perceived pressure can increase the
65 tendency to direct attention inwardly, especially for highly self-conscious athletes. That is,
66 consciously processing and monitoring automated skills may lead to choking (Baumeister,
67 1984; Beilock & Carr, 2001; Hill, Hanton, Matthews, & Fleming, 2011; Jackson, Ashford, &
68 Norsworthy, 2006; Lewis & Linder, 1997; Masters, 1992). Self-focus theories are contingent
69 on stages of learning (Fitts & Posner, 1967). For example, a novice during performance
70 attends to the explicit rule-based aspects of the skill rather than executing the task
71 automatically. According to self-focus theorists, the process of well-learned and automated
72 tasks operates outside working memory, and performance decrements can result from
73 conscious processing and deliberate reinvestment in well-learned skill through working
74 memory (Hill et al., 2010; Masters & Maxwell, 2008). The Explicit Monitoring Hypothesis
75 (EMH; Beilock & Carr, 2001), and the Consciousness Processing Hypothesis (CPH; Masters,
76 1992) are the most renowned and cited self-focus theories. The key distinction is that Beilock
77 and Carr, in describing EMH, state that step-by-step monitoring of performance causes
78 disruption in the execution of skills, whereas Masters, in describing CPH, states that
79 conscious controlling of the performance is detrimental. The available evidence shows that
80 disrupting conscious control supersedes explicit monitoring as a detrimental performance
81 explanation (Hill et al., 2010; Jackson et al., 2006; Marchant, Maher, & Wang, 2014). The
82 Attentional Threshold Hypothesis (ATH; Hardy, Mullen, & Martin, 2001) has been proposed
83 as an alternative hypothesis to explain performance decrements owing to the combination of
84 anxiety-related cognitions and explicit cognitive instructions that exceed the attentional
85 capacity threshold. Anxiety occupies a part of the attentional resources normally required for
86 performance. Hence, diminution of attentional resources has a detrimental effect on
87 performance when both anxiety-related cognitions and explicit instructions occur
88 simultaneously (Gucciardi & Dimmock, 2008; Mesagno, Marchant, & Morris, 2009). The

89 relevant literature generally supports the view that distraction theories are most salient for
90 tasks that mainly demand working memory (e.g., fine motor skills), whereas, self-focus
91 theories are most salient for tasks that do not strongly rely on working memory (e.g., gross
92 motor skills) (Beilock & Carr, 2001; Lewis & Linder, 1997).

93 Sport psychologists have taken a close interest in the causes of choking from multi-
94 dimensional perspectives combining the psychological, social and cognitive dimensions
95 (Baumeister & Showers, 1986; Beilock, Kulp, Holt, & Carr, 2004; Hill, Hanton, Fleming, &
96 Matthews, 2009). Researchers have ascribed the phenomenon of choking to a number of
97 potential antecedents, including the presence of an audience (Wallace, Baumeister, & Vohs,
98 2005), stereotype threat (Chalabaev, Sarrazin, Stone, & Cury, 2008), public status (Jordet,
99 2009), fear of negative evaluation (Mesagno, Harvey, & Janelle, 2012), skill level and task
100 properties (Beilock & Carr, 2001), personal attributes such as self-consciousness (Baumeister,
101 1984), trait anxiety and self-confidence (Baumeister & Showers, 1986; Baumeister, Hamilton,
102 & Tice, 1985; Otten, 2009), coping style (Wang, Marchant, & Morris, 2004), perfectionism
103 (Gucciardi et al., 2010), narcissism (Geukes, Mesagno, Hanrahan, & Kellmann, 2012, 2013;
104 Wallace & Baumeister, 2002), and dispositional reinvestment (Jackson et al., 2006; Masters,
105 Polman, & Hammond, 1993). Although there is now widespread recognition of the
106 antecedents of choking, some potential contributors to performance decline, such as the
107 influence of physiological and situational variables, have not been thoroughly investigated.
108 The pressure of performing well and associated mental effort affects the physiological state of
109 the organism, and the use of coping resources (Laborde, Lautenbach, & Allen, 2015).
110 Qualitative investigations of choking episodes indicate that fatigue, particularly during the
111 final stages of games in team sports, could result in significant under-performance in pressure
112 circumstances (Hill & Shaw, 2013). Murayama and Sekiya (2015) found that under-
113 performance relates to perceived feelings of physical heaviness and weakness. Researchers

114 have recently demonstrated that elite junior basketball players predominantly perform at
115 approximately 85% of maximum heart rate (HR) during games and that metabolic intensity
116 and residual fatigue can influence on aspects of performance such as FT shooting (Padulo et
117 al., 2015). Padulo et al. manipulated the influence of physiological pressure on FT shooting
118 accuracy of participants under three conditions: at rest, 50% and 80% of maximum HR. They
119 reported no significant difference between FT percentage at rest and 50% of the maximum
120 HR (FT percentage about 80%). They did, however, report a significantly lower FT
121 percentage at 80% of maximum HR with accuracy declining to 60%. In a related study, the
122 effect of various exercise intensities on FT accuracy was investigated (Mokou, Nikolaidis,
123 Padulo, & Apostolidis, 2016). Twenty-two, male youth basketball players, performed 50 total
124 FTs under five conditions: at rest and after three-minute shuttle run at four different speeds.
125 Mokou et al. (2016) found a significant effect of exercise intensity on FT accuracy, HR and
126 rate of physical exertion. Moreover, the peak FT performance was observed during average
127 exercise intensity, whereas FT accuracy declined at both rest and high intensity. The
128 contrasting findings of a single-subject design reported no significant effects of physical
129 fatigue on basketball shooting accuracy (Rupčić, Knjaz, Baković, Devrnja, & Matković,
130 2015).

131 Physical exertion as a potential cause of choking has not specifically been examined
132 under varying pressure conditions. The aim of the present study was, therefore, to compare
133 the extent to which physical exertion may affect FT performance under manipulated pressure
134 conditions. We formulated two hypotheses: (a) higher pressure manipulation will significantly
135 reduce performance compared to a lower pressure manipulation, and (b) intense pre-
136 performance physical exertion will significantly reduce performance compared to a low level
137 of pre-performance physical exertion.

138 **Method**139 **Design**

140 A 2×2 repeated measure design was used, with physical exertion (running - no
 141 running) and relative pressure (higher pressure - lower pressure) as the independent variables.
 142 Basketball FT shooting performance was the dependent variable (see Table 1).

143 Table 1

144 *Summary of Design and Variables*

		Pressure	
		Higher pressure	Lower pressure
Physical Exertion	Running	HPR	LPR
	No running	HPNR	LPNR

145 Note. HPR = higher pressure-running; HPNR = higher pressure-no running; LPR = lower
 146 pressure-running; LPNR = lower pressure-no running.

147 **Participants**

148 Seventy-six undergraduate student-athletes initially volunteered to participate in the
 149 study. After a preliminary 10 FT shots trial to assess shooting proficiency, ongoing
 150 participation was restricted to 50 participants (13 female, 37 male), aged 18-26 ($M_{age} = 23.37$
 151 years, $SD = 4.34$). The remaining 26 participants all scored less than four from 10 attempts in
 152 the preliminary trial, and they were excluded to reduce the likelihood of floor effects affecting
 153 the data. That is, all remaining 50 participants scored a minimum 4 out of 10 attempts and
 154 thus demonstrated at least a minimal level of task proficiency ($M_{FT} = 5.74$, $SD = 1.26$)

155 **Measures**

156 **Free-throw (FT) shooting.** The performance task was basketball FT shooting, which
 157 has been widely used as an experimental task in choking studies (Fazel, 2015; Otten, 2009;
 158 Wang, Marchant, Morris, & Gibbs, 2004; Wilson, Vine, & Wood, 2009). Standard basketball

159 equipment and facilities were used, according to specifications of the International Basketball
160 Federation (FIBA). The scoring system adopted here was one point for each successful shot in
161 the two lower pressure conditions and 3 points for each successful shot in the higher pressure
162 conditions. The additional weighting or multiplier in the higher pressure conditions was part
163 of the pressure manipulation.

164 ***Mental Readiness Form-3 (MRF-3)***. The MRF-3 (Krane, 1994) was used to measure
165 perceived state anxiety levels of the participants before each of the four experimental blocks
166 of 10 FTs. The MRF-3 is less invasive and time-consuming compared to longer
167 questionnaires and is suitable when repeated in vivo measurements are required (Beseler,
168 Mesagno, Young, & Harvey, 2016; Wilson et al., 2009). The MRF-3 contains three scales
169 (two-ended continuums, ranged from 1-11). These separate scales measure cognitive anxiety
170 (anchored between calm and worried), somatic anxiety (anchored between relaxed and tense),
171 and self-confidence (anchored between confident and scared). In the present study,
172 participants completed the MRF-3 before commencing each of four trial blocks of 10 FTs, to
173 capture their feelings before initiating the trials.

174 **Procedure**

175 The 76 volunteers responded to the flyers that detailed the general purpose of the
176 experiment. Standard informed consent and information procedures to the participants were
177 followed. The first author explained the aims of the study and the experiment procedure to the
178 participants. To determine shooting proficiency, all participants completed a preliminary FT
179 screening trial, whereby they completed two practice shots then took 10 FTs under the
180 supervision of a research assistant-scorer. The scoring was simply one point for each
181 successful attempt. Participants' scores were then rank-ordered, and the 50 participants who
182 scored four or above were asked to continue in the second phase of the experiment. The

183 remaining 26 participants took the role of audience members in the higher pressure
 184 conditions. To control for order effects, a counterbalanced method was used (see Table 2).

185 Table 2

186 *Counterbalancing Method*

Order	Groups							
	1	2	3	4	5	6	7	8
1	HPR	HPR	HPNR	HPNR	LPR	LPR	LPNR	LPNR
2	LPR	LPNR	LPR	LPNR	HPR	HPNR	HPNR	HPR
3	HPNR	HPNR	HPR	HPR	LPNR	LPNR	LPR	LPR
4	LPNR	LPR	LPNR	LPR	HPNR	HPR	HPR	HPNR

187 Note. HPR = higher pressure-running; HPNR = higher pressure-no running; LPR = lower
 188 pressure-running; LPNR = lower pressure-no running.

189 Participants were randomly assigned to eight groups consisting of six participants in six
 190 groups and seven participants in two groups. Participants rotated through four conditions:
 191 higher pressure-running (HPR), lower pressure-running (LPR), higher pressure-no running
 192 (HPNR), and lower pressure-no running (LPNR). The groups were used to reduce the time
 193 needed to conduct the experiment and to introduce counterbalancing to reduce the likelihood
 194 of order effects. All participants performed 10 FTs in each condition. The running conditions
 195 were designed to investigate the effect of physical exertion on FT shooting performance. The
 196 pressure conditions were designed to investigate the effect of pressure on FT shooting
 197 performance.

198 ***Running conditions.*** In the two running conditions (i.e., HPR and LPR), participants
 199 completed timed shuttle runs, sprinting from the baseline to midcourt and returning to the
 200 baseline repeatedly, thus covering 56 meters in total before completing mini-blocks of two
 201 FTs. To encourage the participants to exert their best efforts in the shuttle-run, participants

202 were also informed that the two fastest male and the fastest female (2:1 ratio based on the
203 total participants) would receive a prize. After each timed shuttle run, the participants
204 immediately walked 10 meters and completed two FTs. This running and shooting protocol
205 was repeated five times until all 10 shots were completed. In the two no-running conditions
206 (i.e., HPNR and LPNR), participants were instructed to walk slowly to the mid-court line after
207 each pair of shots. The experiment was designed to increase physical exertion immediately
208 before the FT task but not induce residual fatigue that could potentially influence later phases
209 of the study. To the same end we ensured there was sufficient time between phases of the
210 study for participants to fully recover from the short-intense running manipulation.

211 **Pressure conditions.** In the two higher pressure conditions (i.e., HPR and HPNR),
212 pressure was manipulated by (a) including the presence of audience (Belletier et al., 2015;
213 Mesagno & Marchant, 2013) of students actively watching the performance from positions
214 located around the key, (b) performance-contingent reward (Beseler et al., 2016; Mesagno et
215 al., 2009) that translated into the top six scorers receiving rewards, ranging in value, from \$15
216 to \$75. The fastest three runners male and female (2:1 ratio) also received a similar choice of
217 rewards, (c) video-recording (Mesagno, Marchant, & Morris, 2008; Otten, 2009) where
218 students were told their shot would be recorded for evaluation purposes and as a possible
219 means to double-check the outcome, and (d) increasing the points for each FT to amplify the
220 relative magnitude of each shot in higher pressure conditions. In the higher pressure
221 conditions, an audience of six student-athletes was placed around the FT rebounding positions
222 (the key) to observe the performance, similar to what occurs in basketball games. The
223 audience was instructed to remain silent, but to convey the attitude of an interested observer
224 and to neither encourage nor discourage the participants. Participants had been briefed to do
225 their best and that at the conclusion of the experiment the two best males and best female FT
226 shooters would receive a prize. For data analyses purposes, however, irrespective of the

227 condition, one point was entered for a successful shot. In the two lower pressure conditions
 228 (i.e., LPR and LPNR), participants performed the FT shot protocol without applying the
 229 manipulated pressure.

230 **Data analysis**

231 All analyses were conducted using the Statistical Package for the Social Sciences
 232 (SPSS). A 2×2 repeated measures analyse of variance (ANOVA) was conducted to examine
 233 potential differences in FT performance among four manipulated conditions and also potential
 234 differences in mental readiness scores among the designed conditions.

235 **Results**

236 *Free-throw (FT) Shooting*

237 Means and standard deviations of FT shooting performance across the four conditions
 238 are shown in Table 3. As expected, participants scored the highest when the pressure was
 239 lower with no physical exertion and scored lowest when both pressure and running were
 240 applied.

241 Table 3

242 *Means and Standard Deviations of Free-throw Scores*

Conditions	M	SD	n
HPR	4.14	2.17	50
HPNR	4.52	1.95	50
LPR	4.62	2.20	50
LPNR	5.34	1.98	50

243 Note. HPR = higher pressure-running; HPNR = higher pressure-no running; LPR = lower
 244 pressure-running; LPNR = lower pressure-no running.

245 Analysis of variance revealed a significant main effect for pressure $F(1,$
 246 $49) = 5.25, p = .02, \eta_p^2 = .09$ corresponding to a medium effect. Participants scored

247 significantly lower in the higher-pressure conditions compared to the lower-pressure
248 conditions. There was also a significant main effect for running $F(1, 49) = 10.13, p = .003,$
249 $\eta_p^2 = .17$ corresponding to a large effect. That is, participants scored significantly higher
250 when not running before shooting compared to running before shooting. There were no
251 significant interaction effects. Based on these results, the alternative hypothesis that FT
252 performance would decline significantly in the higher-pressure conditions compared to the
253 lower pressure conditions was accepted. Similarly, the alternative hypothesis that FT shooting
254 would decline significantly in the higher physical exertion conditions compared to the low
255 physical exertion conditions was also accepted. The main story in the present research was
256 that manipulated pressure and physical exertion both cause choking, but are independent of
257 each other. Furthermore, additional follow up regression analysis to detect whether gender
258 predicted poor performance under higher pressure and running conditions was not significant.

259 ***Mental Readiness Form-3 (MRF-3)***

260 To analyse the potential influence of anxiety on performance, we computed a repeated
261 measure analysis of variance using MRF-3 scale scores. For the cognitive anxiety scale, No
262 significant differences were found for the MRF-3 sub-scales in either the manipulated
263 pressure conditions or running conditions.

264 **Discussion**

265 The aim of the present research was to investigate the effects of perceived pressure and
266 physical exertion on basketball FT shooting performance. The results provide an insight into
267 the relatively untested effects of physical exertion on performance under differential pressure
268 and confirmed the a priori hypotheses that both the pressure manipulation and the pre-
269 shooting running manipulation would produce significant downward effects on FT shooting
270 accuracy.

271 The ability to successfully execute FTs is generally accepted as critical and potentially
272 decisive in close basketball games, particularly in the final phase of games where players
273 experience a combination of pressure, fatigue, and various emotions linked to the imminent
274 game outcome (Gómez, Lorenzo, Jiménez, Navarro, & Sampaio, 2015). For example,
275 analysts have shown that winning teams obtain approximately two-thirds of their score in the
276 final three minutes of play from successful FTs (Lorenzo Calvo, Gómez Ruano, Ortega Toro,
277 Ibañez Godoy, & Sampaio, 2010). The pressure to successfully convert FTs in the final
278 seconds of close games (± 3 points) in the most high-profile leagues, combined with residual
279 game fatigue, represent an ideal platform from which to contextualize the results of the
280 current research. That is, the current finding, that FT shooting performance declined
281 significantly under conditions of higher pressure and higher physical exertion, reflects the
282 types of performance decline that researchers have reported occurring in the final seconds of
283 super elite leagues (Cao, Price, & Stone, 2011; Gómez et al., 2015; Ibañez, Santos, & García,
284 2015; Toma, 2015). Toma (2015), for example, has recently reported FT shooting trends
285 using reliable archival data extracted from the highly elite samples of players participating in
286 the NBA, the Women's National Basketball Association (WNBA), and also the men's and
287 women's National Collegiate Athletic Association (NCAA) between 2002-2013. By
288 analysing over two million FT attempts, Toma reported that these super-elite players
289 experience a substantial decline in FT shooting performance in the crucial final 30 seconds of
290 close games (5.81%, 3.11%, 2.25% and 2.09% point declines in the WNBA, NBA, women's
291 NCAA and men's NCAA, respectively). In the present study, the FT under-performance
292 range across the four manipulated conditions was 1% - 12%. From a comparative perspective,
293 a 5 - 10% FT performance decrease has been reported in the final seconds of close games in
294 the NBA. Cao et al. (2011) analysed all FTs in the NBA between 2002 - 2010. The FT
295 percentage declined 4% when the margin was ± 2 points in the final minute. A further

296 breakdown of the FT shooting trends in the final 15 seconds of games corresponded to a 6.3%
297 decline when a team was down by 2 points and an 8.8% decline when a team was down by 1
298 point. In summary, the results of the current study reflect what happens in the field (i.e., high-
299 level basketball competition). We emphasize this point because demonstrating results that are
300 consistent with actual competition, is an important indicator of external validity. In this
301 instance, we believe the experiment results to be both relevant and relatively important within
302 the game performance context.

303 The results of the current study are consistent with previous choking studies from the
304 pressure manipulation perspective (Beseler et al, 2016; Kinrade, Jackson, & Ashford, 2015;
305 Mesagno & Marchant, 2013; Mesagno et al., 2008, 2009; Otten, 2009; Schücker, Hagemann,
306 & Strauss, 2013). That is, a relative increase in manipulated pressure typically leads to a
307 significant deterioration in performance. The relevant literature supports the view that
308 distraction theories are most salient for tasks that strongly rely on working memory, whereas
309 self-focus theories are most salient for tasks that are less reliant on working memory (Beilock
310 & Carr, 2001; Lewis & Linder, 1997). Moreover, the predominant theories have been
311 reported to predict choking depending on the skill level of athletes. Distraction theories can
312 explain choking under pressure for novice players while self-focus theories can explain
313 choking for more skilled players (Beilock & Gray, 2007). We believe a combination of both
314 distraction and self-focus theories supports the findings of the current study, because we used
315 student-athletes with a wide range of abilities, from domestic competition through to sub-elite
316 competition, as the participants. Based on distraction theories, execution of the task can lead
317 to performance deterioration, because attention shifts to irrelevant task cues or thoughts such
318 as concerns about the consequences or the situation (Beilock & Carr, 2001; Lewis & Linder,
319 1997). Performance decrements often occur when irrelevant thoughts consume working
320 memory that is required to execute the task. High-pressure situations can overwhelm

321 attentional resources and negatively influence accomplishment of the task (Beilock &
322 DeCaro, 2007; Gimmig, Huguet, Caverni, & Cury, 2006; Markman et al., 2006). The less
323 skilled participants who performed poorly in the present study, would have needed to allocate
324 additional working memory to execute the task under the manipulated pressure conditions
325 where other distractions likely occupied their working memory. Hence, the distraction theory
326 seems the most appropriate explanation for novice and less skilled participants. Based on self-
327 focus theories, explicitly attending to task execution can result in performance decrements
328 (Baumeister, 1984; Beilock & Carr, 2001; Hill et al., 2011; Masters, 1992). The more skilled
329 participants who performed poorly under pressure may have attended consciously to the FT
330 task rather than trusting automaticity. Despite the expected findings that FT performance
331 deteriorated under higher pressure and running one anomaly remained that subjective anxiety
332 levels as measured by the MRF-3 were not significantly different across conditions. The
333 MRF-3 has not been widely used in sport anxiety research and generally the CSAI-2 has been
334 favoured. With the benefit of hindsight we do have comments and concerns about the MRF-3
335 that researchers conducting similar studies may consider. We observed that completion times
336 for the MRF-3 were exceptionally short and the participants did not seem to read or reflect in
337 the style normally produced by longer questionnaires. Psychometricians have also raised
338 concerns about the validity of questionnaires that use a single item to measure a scale and
339 generally recommend using multiple item to measure a scale (e.g., Furr, 2011;
340 Hatzigeorgiadis & Chroni, 2007; Hinkin, Tracey, & Enz, 1997).

341 The results of the present study are consistent with research demonstrating that fatigue
342 (i.e., sustained physical exertion can precipitate under-performance in pressure circumstances
343 (Hill & Shaw, 2013; Laborde et al., 2015; Mokou et al., 2016; Murayama & Sekiya, 2015;
344 Padulo et al., 2015). For example, researchers in two recent studies demonstrated that
345 metabolic intensity due to fatigue decreased FT accuracy (Padulo et al., 2015), and also

346 exercise intensity had a significant effect on FT accuracy, HR and rate of perceived exertion
347 (Mokou et al., 2016). Results of the present study support the findings of Mokou et al. (2016)
348 and Padulo et al. (2015) and demonstrate that physical exertion may lead to performance
349 decrements especially under pressure circumstances.

350 In relation to the experimental manipulations in the present study, the pressure variable
351 was modest in the context of what would be likely to be experienced in actual competition.
352 Similarly, the physical exertion required in the current experiment was relatively minimal in
353 comparison with the repeated intense physical exertion routinely experienced in basketball
354 competition. Nevertheless, we recommend caution when interpreting the current findings. For
355 both ethical and ecological reasons, participants were exposed to an increase in manipulated
356 pressure. This limitation may ironically heighten the expectation that the effects of pressure
357 and physical exertion might be stronger in actual competitions where more intense pressure is
358 likely to be experienced. Likewise, the participants were exposed to an increase in physical
359 exertion. However, the brief shuttle-run task would likely produce only a modest and short-
360 term physiological effect compared to the intense extended efforts often required of players in
361 actual game situations. To place the performance changes in a competitive context and
362 encourage participants to apply more effort, we offered performance-contingent rewards.
363 Although we used a pre-test to measure the FT shooting skill level of participants, we did not
364 specifically measure the relative fitness level of participants. Anecdotally, we did, however,
365 observe that those participants with observably better levels of fitness appeared to be more
366 capable of executing the FT task successfully in the two running conditions. Also, researchers
367 pursuing this line of research might consider measuring the actual physical exertion precisely,
368 through known means such as precise monitoring of HR, cortisol levels, and blood lactate.
369 Researchers might consider examining whether relative fitness and relative exertion have a
370 moderating influence on performance under pressure. For example, monitoring HR using

371 wristband telemetry, to ensure that participants reached a specified criterion level of fatigue
372 before executing the performance task, might be used where non-invasive data collection is
373 required in field settings.

374 Furthermore, although we used a pre-test to examine relative FT shooting ability to
375 screen out relatively unskilled participants, and avoid floor effects, the range of abilities for
376 the remaining participants was relatively broad (i.e., pre-test scores ranging from 4 - 9 in the
377 10 shot trial). Hence, recruiting participants from relatively narrow skill ranges may help to
378 avoid the variability in the participant sample skill range. Also, one of the difficulties for
379 choking studies is to address the issue of the reproducibility of choking, since creating
380 stressful circumstances similar to real world situations is problematic, both practically and
381 ethically. All participants in the current study had played competitive basketball. However,
382 the participation range included domestic level basketball through to sub-elite level
383 basketball. Nevertheless, deliberately recruiting an entirely sub-elite or elite sample presents
384 other issues, such as the likely need to increase the intensity of the pre-shooting physical
385 activity to produce commensurate physical exertion. More particularly, a balance needs to be
386 struck between the level of manipulated pressure required to produce a discernible difference
387 between lower and higher pressure manipulations, without contravening the strict cost-benefit
388 boundaries that university ethics committees require.

389 **Conclusions**

390 The results of the present study extend previous research by demonstrating that physical
391 exertion immediately before performance increases the likelihood of choking occurring. This
392 has relevance for researchers, basketball players, basketball coaches and applied sports
393 psychologists. Researchers might investigate whether these findings carry across to other
394 sports that involve self-paced performance tasks (e.g., dart throwing, archery, penalty/set shot
395 goal kicking and the tennis serve) intermittently and immediately after physical exertion.

396 Basketball players who struggle with shooting under pressure would likely be interested to
397 know that physical exertion can exacerbate the negative effects of performing under pressure.
398 Basketball coaches might reflect on the results of the present study to modify training to
399 prepare players better for shooting in pressure circumstances (e.g., rehearse FT shooting
400 immediately after intense physical exercise under pressure conditions). Furthermore,
401 regarding external validity, the current results are immediately relevant to the sport of
402 basketball, but also potentially relevant to other sports that require participants to perform
403 self-paced tasks under pressure when preceded by physical exertion. Researchers might
404 further investigate the effects of physical exertion on performance by manipulating the
405 intensity of exertion and level of residual fatigue (e.g., early, middle and late game). Such
406 research should be useful for coaches aiming to prepare athletes better for performing under
407 pressure. Applied sport psychologists may be already aware of the numerous choking
408 antecedents identified in the academic literature. They may also be aware of the choking
409 specific interventions that have been used to ameliorate choking. The results of the present
410 study should add to the relevant evidence-based knowledge that practitioners need to consider
411 when designing client interventions.

412 The current results can be contextualised by revisiting accepted definitions of choking.
413 For example, based on the Baumeister's (1984) definition that choking is "performance
414 decrements under pressure situations," we believe that choking occurred in the present study.
415 Alternatively, by applying the more recent definition of Mesagno and Hill (2013) that "an
416 acute and considerable decrease in skill execution and performance when self-expected
417 standards are normally achievable, which is the result of increased anxiety under perceived
418 pressure" arguably the decline in performance many not have been sufficient to justify
419 applying the choking label. That is, the level of under-performance in the present study was
420 not necessarily acute, but it was statistically significant. We consider our results consistent

421 with the findings of Toma (2015) who clearly showed that under-performance in pressure
422 circumstances at the most elite levels is not necessarily acute, but is a systematic and robust
423 finding. Thus regarding the applicability of the Mesagno and Hill definition, a considerable
424 but not necessarily acute decrement occurred in both the present study and the Toma's study.
425 Toma argued that the highest level of basketball players can choke in the final seconds of
426 close games. Hence, the label choking is not only dependent on which definition of choking is
427 cited but the circumstances or context in which the underperformance occurs. We invite other
428 researchers also to examine how physical exertion can affect performance with other tasks,
429 sports, and circumstances.

430

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