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Effect of Heart rate On Basketball Three-Point Shot Accuracy

1

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14 **Abstract**

15 The three-point shot (3S) is a fundamental basketball skill used frequently during a game, and is
16 often a main determinant of the final result. The aim of the study was to investigate the effect of
17 different metabolic conditions, in terms of heart rates, on 3S accuracy (3S%) in 24 male (Under 17)
18 basketball players (age 16.3 ± 0.6 yrs). 3S performance was specifically investigated at different heart
19 rates. All sessions consisted of 10 consecutive 3Ss from five different significant field spots just
20 beyond the FIBA three-point line, i.e., about 7 m from the basket (two counter-clockwise “laps”) at
21 different heart rates: rest (0HR), after warm-up (50%HRMAX [50HR]), and heart rate corresponding
22 to 80% of its maximum value (80%HRMAX [80HR]). We found that 50HR does not significantly
23 decrease 3S% (-15%, $P=0.255$), while 80HR significantly does when compared to 0HR (-28%,
24 $P=0.007$). Given that 50HR does not decrease 3S% compared to 0HR, we believe that no preliminary
25 warm-up is needed before entering a game in order to specifically achieve a high 3S%. Furthermore,
26 3S training should be performed in conditions of moderate-to-high fatigued state so that a high 3S%
27 can be maintained during game-play.

28 **1 Introduction**

29 Due to its mixed physical-technical-tactical nature, basketball practice, like in other team sports,
30 requires great attention to profiling the relevant physical and physiological characteristics of elite
31 basketball players and, contextually, to determining the relationships between all of its features (e.g.,
32 metabolic demands) and the required technical skills. By investigating the typical game-driven
33 physiological responses, recent research has widely determined the on-court activity patterns and the
34 position-specific physical demands of this sport (Nikolaidis *et al.*, 2014; 2015). In this regard, a body

35 of studies has provided construct validity and reliability of physical assessment tests designed
36 according to the running profile and activity patterns of the basketball players, by the inclusion of
37 single or multiple changes of direction (Padulo *et al.*, 2015b). Given the multi-faceted nature of
38 basketball, whose performance success is a matter of physical, technical, and tactical ability, studies
39 have been carried out as well regarding technical skills, such as the shooting task (Padulo *et al.*,
40 2015a). A recent review (Okazaki *et al.*, 2015) has reported that the ability to shoot an effective jump
41 shot is critical for the player's success. Other findings are that players shoot more frequently in low-
42 pressure and streaky situations (Csapo *et al.*, 2015), and that compared to amateur players,
43 professionals are able to shoot from greater distances and use more collective actions to find a shot
44 position in which, possibly, the defensive pressure is lower (Ibáñez *et al.*, 2009). Differences by
45 playing position have been identified in short performers: point guards and power forwards shoot the
46 most often and with the best accuracy in free-throw and two-point shots, whereas point guards shoot
47 the most often and with the best accuracy in three-point shots (Ortega *et al.*, 2006).

48

49 The abovementioned studies on factors influencing shooting performance have improved our
50 understanding about the key factors targeted as fundamental for shooting performance accuracy.
51 However, less information is available on the effect of fatigue, i.e., the variation of shooting accuracy
52 over different exercise intensities, on the three-point shot (3S). In sport science, fatigue effects
53 received attention, mainly because fatigue impacts overall athletes' performance (Faria *et al.*, 2005).
54 Harmful fatigue effects can diminish the function of a single whole-muscle, which leads to reduced
55 muscle performance and therefore can decrease overall athletes' competition efficacy (Knicker *et al.*,
56 2011). Fatigue can be described as a complex mechanism that involves both central and peripheral
57 nervous system together with muscles (i.e., motor units; Ahmed, 2013). Poor perceptions, decisions,
58 reactions, and resultant movement strategies are more likely to happen when athlete is in a fatigued
59 state because central processing mechanisms and peripheral responses are compromised (Borotikar *et al.*,
60 2008). In particular, the decision-making, considered as a high cognitive process, is closely
61 related to fatigue and it can be said that a relation does exist between intensity and duration of the
62 physical activity and this cognitive function (Abd-Elfattah *et al.*, 2015). Commonly identified as an
63 outcome of intense physical activity, fatigue has also been considered as a subjective experience,
64 which can be described as a "sensation" (St Clair Gibson *et al.*, 2003). Each individual has different
65 sensations of fatigue and their generation is largely independent on the real biological state of the
66 athlete, because brain uses the symptoms of fatigue as key regulators to protect body from potential
67 damages (Noakes, 2012). Moreover, fatigue affects muscle strength, coordination, fine motor control,
68 and movement patterns (Enoka and Stuart, 1992). Basketball players have high capability to move
69 quickly, jump, and bounce the ball coordinating lower and upper limb movements (Cortis *et al.*,
70 2011) and to achieve efficient basketball performance it is important to understand body adaptations
71 and compensations under acute fatigue. Basketball players must be able to effectively perform
72 specific tasks under conditions of physical fatigue that occurs during different training and game-play
73 intensities (Kamandulis *et al.*, 2013). Specifically about shooting performance, Barbieri *et al.* (2017)
74 investigated fatigue effect on free-throw accuracy. They administered players a shuttle running
75 fatiguing protocol and found postural control impairment but no free-throw accuracy decrease. Yet,
76 by administrating such a protocol, they did not aim at achieving any reasonable heart rate-witnessed
77 warm-up (Garrett and Kirkendall, 2000) and/or actual play (McInnes *et al.*, 1995) metabolic intensity
78 values.

79

80 Three-point shot performance is one of the main win determinants in elite basketball. Keeping a high
81 3S percent accuracy (3S%), especially during final minutes of close games, shows to be a key to
82 success. Just as a reference, in the 2015-16 season (regular season and playoffs), the NBA champions
83 Cleveland Cavaliers shot –contested by players from the opposing team – 3Ss in the first and last 2
84 minutes of regular quarters, and overtimes with a 3S% of 38.4 and 32.5%, respectively¹. 3S is a
85 common fundamental shot, which can be performed both when the players just come off the bench
86 and when they are fatigued by previous actions. Knowledge about the effects of exercise intensity on
87 3S% would be of great importance for both sport scientists and basketball practitioners (e.g., coaches
88 and fitness trainers). Since no previous study has been performed on this topic (Padulo *et al.*, 2015a),
89 sport scientists could use any further information as reference data for future studies on a basketball
90 task performance and analysis model. In addition, coaches and fitness trainers might benefit from
91 such knowledge in order to develop suitable exercise interventions for optimizing shooting accuracy.
92 Therefore, the aim of the present study was to examine the effect of different heart rates on
93 successful 3S%. We hypothesized that increasing heart rate would pair with decreasing 3S%.

94

95 **2 Material and Methods**

96 **2.1 Participants**

97 Twenty-four young (Under 17) basketball players (age 16.3 ± 0.6 yrs, height 180 ± 6.1 cm, mass
98 65.7 ± 7.2 kg, BMI 18.3 ± 1.7 kg/m², training experience 8.7 ± 2.6 yrs) were recruited from
99 Associazione Dilettantistica Basket Club 7 Laghi Gazzada Schianno teams. All players, in addition
100 do their weekly practice, participated in the seasonal championship made up of a regional phase, an
101 inter-regional phase, and national 16-team finals. Inclusion criteria to participate in the study were: i)
102 participation in at least 85% of the previous season training sessions, ii) regularly participating in the
103 previous competitive season, iii) having a valid sport medical certification, and iv) being healthy (no
104 pain or injury) and clear of any drug consumption. Participants refrained from drinking alcohol or
105 caffeine-containing beverages for 24 hours, and did not eat for 3 hours, prior to testing to reduce any
106 interference on the experiment. Each participant completed all trials in the same time period of the
107 testing days (during the pre-season) and under the same climate conditions (4-7 p.m., 23.2 ± 0.6 °C
108 temperature and 55.3 ± 1.8 % relative humidity [i.e., day times and climate conditions similar to real
109 game-play]), to eliminate any influence of circadian variation. All tests were performed on a regular
110 indoor basketball court and the participants wore their official basketball uniforms. Participants gave
111 their assent, and written consent was obtained from the participants' parents/guardians after being
112 thoroughly informed about the purpose, benefits, and potential risks of the study, in conformity with
113 the Code of Ethics of the World Medical Association (Declaration of Helsinki). The protocol and the
114 methods applied in the study were approved by the Ethical Committee of the Faculty of Kinesiology,
115 University of Split.

116

117 **2.2 Protocol**

118 In the first session the participants performed a Yo-Yo Intermittent Recovery test level 1 (Yo-Yo
119 IR1; Castagna *et al.*, 2008b) to assess maximal heart rate (HRMAX). One week later the participants

¹ BASKETBALL REFERENCE, http://www.basketball-reference.com/play-index/plus/shot_finder.cgi

120 performed three randomized shooting testing sessions, with a one-hour rest plus warm-up between
 121 one session and the next one. All sessions consisted of 10 consecutive 3Ss (ball – Molten gf7, 600
 122 gr.) from five different significant field spots just beyond the FIBA three-point line, i.e., about 7 m
 123 from the basket (similar to the NBA All-Star Weekend Three-Point Contest shots²; Figure 1, two
 124 counter clockwise “laps”) at three different heart rates (HR): rest (0HR), after warm-up with HR at
 125 50%HRMAX (50HR; i.e., a reasonable post-warm-up HR value; Garrett and Kirkendall, 2000), and
 126 80%HRMAX (80HR; i.e., a reasonable actual play HR value; McInnes *et al.*, 1995), repeating the
 127 approach used by Padulo *et al.* (2015a). The same procedure was repeated one week later to evaluate
 128 the measures’ reliability. More specifically, after a 15’ standard warm-up run, each participant threw
 129 10 consecutive 3Ss at different HRs (0HR - 50HR - 80HR). Each HR (continuously monitored with
 130 Cardio-Suunto™) was achieved by increasing the intensity of the shuttle running (15+15 m).
 131 Namely, the participants needed to run an average of 560 m and 1600 m to achieve 50%HRMAX and
 132 80%HRMAX, respectively (i.e., to elicit a post-warm-up- and actual play-like fatigued state).

133

134 2.3 Statistical analysis

135 Measures of central tendency and dispersion (mean±SD and SE) were computed from the Yo-Yo IR1
 136 and 0HR, 50HR, and 80HR (effective %HRMAX and measured 3S%) test results to summarize the
 137 data. Statistical analyses were performed with SPSS 17.0 (SPSS Inc., Chicago, IL). Distribution
 138 normality of the population was tested with the Shapiro-Wilk test, and homogeneity of variances was
 139 verified with Bartlett’s test. The reliability of the 0HR, 50HR, and 80HR tests was assessed by
 140 calculating the Intra-class Correlations Coefficient (ICC), according to the literature (Weir, 2005).
 141 Furthermore, a one-way within-participant’s repeated-measures analysis of variance (ANOVA) was
 142 conducted to check for differences between the three test levels (0HR, 50HR, and 80HR) with a post-
 143 hoc Bonferroni test. Effect sizes are presented as partial eta-squared (η^2_p) to determine the
 144 meaningfulness of the results. As suggested by Cohen (1992), threshold values for effect size were
 145 0.01 (small), 0.06 (medium), and 0.14 (large). Level of statistical significance was set at a *P*-
 146 value \leq 0.05.

147

148 3 Results

149 ICC showed a good reliability at 0HR (0.88), 50HR (0.91), and 80HR (0.94). Yo-Yo IR1-derived
 150 HRMAX was 195.6±6.1 bpm, obtained with a covered distance of 1,878±568 m and a final speed of
 151 18.4±1.8 km/h. ANOVA confirmed differences of HR over the three administrated exercise
 152 conditions (Figure 2, top; $F_{(1,22)}=3405.722$, $P<0.0001$, $\eta^2_p=0.990$ at 0HR 54.4±3.1 bpm, at 50HR
 153 99.2±4.6 bpm, and at 80HR 155±6.5 bpm). Similarly, ANOVA showed differences of 3S% over the
 154 three exercise conditions (Figure 2, bottom; $F_{(1,22)}=5.068$, $P=0.009$, $\eta^2_p=0.131$). 3S% in the three
 155 exercise conditions was 46.8±12.3% at 0HR, 41.3±10.7% at 50HR, and 36.8±9.5% at 80HR. The
 156 Bonferroni test did not show any significant 0HR-50HR 3S% (-15%, $P=0.255$) or 50HR-80HR (-
 157 12%, $P=0.255$) differences, whereas 80HR elicited significantly lower values of 3S% compared to
 158 0HR (-28%, $P=0.007$).

159

² NBA ALL STAR, <http://www.nba-allstar.com/contests/3point/>

160 4 Discussion

161 The major question of this study was whether there is any effect of different heart rates on successful
 162 three-point shot (3S) percentage (3S%). Therefore, three different heart rates were elicited to
 163 investigate 3S% in young male basketball players: rest (0HR), after warm-up with heart rate (HR) at
 164 50%HRMAX (50HR), and 80%HRMAX (80HR). According to the results, the main findings of the
 165 present study can be summarized as follows: (i) 50HR does not significantly decrease 3S%, while on
 166 the other hand (ii) 80HR (i.e., intensity similar to that in real game-play; Abdelkrim *et al.*, 2010)
 167 significantly decreases 3S%. The difference in 3S% between 0HR and 50HR was about -15%,
 168 whereas the difference between 0HR and 80HR was (significantly) -28%. The adverse effects of
 169 fatigue on performance and skills in basketball (Ahmed, 2013; Lyons *et al.*, 2006; Padulo *et al.*,
 170 2015a) have been reported in studies on other sports, such as tennis (Rota *et al.*, 2014), water polo
 171 (Royal *et al.*, 2006), and soccer (Russell *et al.*, 2011). The results obtained by Padulo *et al.* (2015a)
 172 on the effect of fatigue on successful basketball free-throw (FT) percentage (FT%) are similar to the
 173 results of this study. The authors (Padulo *et al.*, 2015a) reported that fatigue caused a decrease in
 174 FT% from -22% (between 80HR and 50HR) to -23% (between 80HR and 0HR). Both FT and 3S are
 175 complex basketball fundamentals, but are ecologically performed under very different game-play
 176 conditions. The FT is characterized by the fact that it is uncontested, which means that the shooter
 177 can be disturbed in a limited manner only by the opposing fans' movements and shouts (Padulo *et*
 178 *al.*, 2015a). FT, which is a penalty for a player or team foul, contributes to from 15% to 21% of the
 179 total points scored during the game³. As a predominantly anaerobic sport, most of the energy demand
 180 for basketball's high-intensity activities, such as changes of direction, jumps, and shots, comes from
 181 the creatine phosphate system (CP; Metaxas *et al.*, 2009). Yet a high fraction of maximum oxygen
 182 consumption is needed for recovery from such high-intensity activities (Tomlin and Wenger, 2001);
 183 it is therefore crucial for a player to recover in order to shoot successful FTs. A high level of aerobic
 184 fitness allows players to make a quick recovery after high-intensity activities, since muscle CP stores
 185 may be replenished within 30-40 s (Castagna *et al.*, 2008a). It should be noted that in practice, a
 186 player is usually allowed about 30 s to shoot each FT (Padulo *et al.*, 2015a).

187

188 In contrast, the 3S shooter must complete a motor action that is far more complex in order to achieve
 189 his successful task, i.e., managing the related decision making under fatigue, in a very small time
 190 frame (often with the approach of the shot-clock end), and with the opposition of one or more
 191 defenders (Oudejans *et al.*, 2005). In addition, potential off-court disturbance, such as visual
 192 distractions, can slightly change FT's kinematics but without decreasing its accuracy (Viggiano *et al.*,
 193 2014). Two- (2S) and three-point shots provide the most points contributions during a match, with
 194 total score percentages of 51-67%⁴ and 16-35%⁵, respectively. 2S and 3S shots are the results of
 195 rapidly unfolding attack game plans, which very often include high-intensity movements. Given that
 196 the 3S requires more coordination and strength, elite basketball players can incur potentially more
 197 negative effects due to fatigue than in sub-maximal performances requiring relatively less overall

³ 2015-16 NBA season, TEAMRANKINGS, <https://www.teamrankings.com/nba/stat/percent-of-points-from-free-throws?date=2016-06-20>

⁴ 2015-16 NBA season, TEAMRANKINGS, <https://www.teamrankings.com/nba/stat/percent-of-points-from-2-pointers?date=2016-06-20>

⁵ 2015-16 NBA season, TEAMRANKINGS, <https://www.teamrankings.com/nba/stat/percent-of-points-from-3-pointers?date=2016-06-20>

198 effort such as FT (Uygur *et al.*, 2010). In basketball, shot performance requires a highly coordinated
199 entire body, from feet to hands, and this is especially true for long-range shots and 3Ss⁶ (Okazaki and
200 Rodacki, 2012). Explosive movements, featuring fundamentals such as the jump shot and 3S, make
201 fatigue effects on shooting accuracy even more relevant. Three-point shot accuracy decreases likely
202 due to different reasons. We investigated its change (i.e., decrease) over changing metabolic demand
203 (i.e., heart rate increase). What we found is at least a statistically significant link between the two
204 signals. Like Padulo *et al.* (2015a) and Erculj and Supej (2009), we conclude that the training of
205 shooting – be it FT or 3S – should be performed in conditions of from moderate-to-high fatigued
206 state as well, so that an appropriate shooting technique can be preserved and will result in higher
207 shooting accuracy during game-play.

208

209 **5 Conclusions**

210 As a practical implication for coaches and players, given that 50HR does not significantly decrease
211 3S% with respect to 0HR, no preliminary warm-up is needed by the players before entering the
212 game. In addition, since 80HR significantly decreases 3S% with respect to 50HR, it has come to light
213 that 3S training in conditions of from moderate-to-high fatigued state is necessary to maintain high
214 3S% during game-play. The results of this study should prompt future studies on the effects of
215 fatigued state on shooting accuracy – not limited to 3S but also on further (coordination-driven!)
216 fundamentals such as defence ones – that administers fatiguing protocols more ecological than basic
217 shuttle running, e.g., real attack game plans. It would be interesting to use alternative metabolic
218 intensity proxies, such as Karvonen’s HR reserve (Karvonen *et al.*, 1957) and/or rate of perceived
219 exertion (Borg, 1982), as well. In terms of study limitations, it should be considered with caution that
220 results were obtained under very controlled conditions, while real game-play takes place in a
221 sometimes chaotic setting characterized by opponents of varied levels, numerous score differences,
222 opposing fans’ behaviour, etc.). Basketball statistics have provided indications about other
223 confounding factors as well, such as shooters shooting better when defended and shooters scoring
224 several points over a stretch of time without any special reason⁷ (i.e., the “hot-hand phenomenon or
225 fallacy”, “streaky” shooters, and/or the “Matthew effect”; Arkes, 2010; Csapo *et al.*, 2015; Csapo and
226 Raab, 2014; Gilovich *et al.*, 1985; Koehler and Conley, 2003; Wardrop, 1995). Another study
227 limitation, that could prompt further studies, is that we did not considered heart rate effect on 3S% in
228 different playing positions and/nor elite adult players (we chose to investigate a typical whole youth
229 team). In conclusion, different metabolic conditions also affect a relevant basketball fundamental
230 such as 3S, and coaches and trainers should consider this when designing effective specific training
231 regimes.

232

233 **6 Conflict of Interest**

234 *The authors declare that the research was conducted in the absence of any commercial or financial*
235 *relationships that could be construed as a potential conflict of interest.*

236 **7 Author Contributions**

⁶ BASKETBALL REFERENCE, http://www.basketball-reference.com/play-index/plus/shot_finder.cgi

⁷ NBA, <http://stats.nba.com>

237 All authors contributed equally to this work.

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361 **Figure Legends**

362 **Figure 1.** Three-point shot spots.

363 **Figure 2.** Heart rate (HR (%HRMax), top) and three-point shot percent accuracy (3S accuracy (%),
364 bottom), as mean \pm SD, over the three different testing conditions. * $P < 0.05$.