The Effect of Acute Exercise on Pistol Shooting Performance of Police Officers

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Previous studies indicate that rifle shooting performance while standing is compromised when fatigued. Apprehension of suspects by police officers may involve foot pursuit and firing a weapon from a standing position. The purpose of the current study was to investigate pistol shooting performance in police officers under similar conditions of physical fatigue. Participants (mean age: 30.1 years; 4.4 years of experience as police officer) completed two shooting trials separated by an acute bout of exercise on a cycle ergometer to voluntary exhaustion. Each trial consisted of three rounds of five rapid-fire shots at a target, each round separated by a 15-s rest. Participants’ backs were turned to the target between rounds. Despite physical exertion, with an average heart rate of 164 bpm, shooting accuracy (mean distance of the closest 4 shots from the center of the target) and precision (diameter of the tightest 4-shot grouping) remained unchanged on postexercise trials relative to preexercise trials. This suggests that automatic shooting reactions override the adverse consequences of fatiguing exercise on shooting performance.

Keywords: fatigue, shooting accuracy, shooting precision

Duties of police officers include apprehending suspects which may involve foot pursuit and, in some cases, firing a weapon at a suspect. Accuracy in firing a weapon is a priority in these confrontations to minimize the risks of unintended injury to the officers involved and for the safety of innocent civilians. A potential risk factor in those situations is the officers’ fitness level. Police work is largely sedentary and not physically demanding. It has been estimated that 80–90% of police tasks require limited physical abilities (Bonneau & Brown, 1995). Thus, the physical demands of police work are not sufficient to maintain physical fitness (Pollock, Gettman, & Meyer, 1978; Stamford, Weltman, Moffatt, & Fulco, 1978; Smolander, Louhevaara, & Oja, 1984; Bonneau & Brown, 1995). Consequently, when officers find it necessary to engage in foot pursuit of a suspect, their fitness may be a determining factor in the outcome.

Shooting performance has been characterized by accuracy (i.e., deviation from target), precision (i.e., consistency), and stability of hold (Hoffman, Gilson, Westenburg, & Spencer, 1992). Increases in postural sway and heart rate have been

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cited as factors contributing to diminished shooting performance (Evans, Scoville, Ito, & Mello, 2003). Peripheral muscular fatigue provoked by short-duration, high-intensity exercise has been shown to affect postural stability as evidenced by an impaired ability to maintain a steady, upright position (Dickin & Doan, 2008). In contrast to shooting from the prone position, leg fatigue has been found to affect performance when shooting from the standing position (Hoffman et al., 1992). The fatigue effect is compounded in pistol shooting where arm tremor and body tremor also influence shooting performance (Goonetilleke, Hoffmann, & Lau, 2009; Lakie, 2010). As the gun is held in one hand with the arm extended, minor movements of the outstretched hand are a normal phenomenon and are thought to represent the efforts of the nervous system to control position (Lakie, 2010). Adding a load to the extended arm accentuates this movement. Exercise-induced increases in heart rate and ventilation further contribute to the tremor (Lakie, 2010). Thus, the physiological response to exercise is opposite to that needed in target shooting.

The influence of physical fatigue on postural and arm movement control might lead to the expectation that the shooting performance of police officers would suffer with physical exertion. Yet, there are other factors that might counteract those potentially detrimental influences. The automaticity of shooting resulting from extensive training (Haufler, Spalding, Santa Maria, & Hatfield, 2000; Kerick, Douglass, & Hatfield, 2004; Oudejans, 2008) may allow officers to maintain their performance even when fatigued. Furthermore, having a supra-postural goal (e.g., aiming with a pistol, holding an object still, pointing, touching, looking) has been shown to result in spontaneous reductions in postural sway to facilitate the achievement of the supra-postural goal (Riley, Stoffregen, Grocki, & Turvey, 1999; Stoffregen, Pagulayan, Bardy, & Hettinger, 2000; Stoffregen, Smart, Bardy, & Pagulayan, 1999). This effect may offset any additional tremor resulting from leg fatigue. Increases in postural stability on tasks that involve supra-postural goals are particularly pronounced when the individual focuses attention externally, that is, on achieving the environmental goal of reducing movements of an object being touched (McNevin & Wulf, 2002) or held (Wulf, Mercer, McNevin, & Guadagnoli, 2004; Wulf, Weigelt, Poulter, & McNevin, 2003). An external focus of attention on the intended movement outcome—such as shooting at a target—has been shown to promote movement automaticity, with the consequence that the outcome is achieved accurately, reliably, and efficiently (for reviews, see Wulf, 2007, 2012).

The purpose of this study was to investigate the effects of acute, exercise-induced leg fatigue on shooting performance in police officers. We hypothesized that experienced police officers would not demonstrate a decline in shooting performance after a bout of exercise, relative to baseline performance, due to the mechanisms described above.

Method

Participants

Eight active police officers, with a mean age 30.1 years (SD: 5.9) and 4.4 years (SD: 2.0) of experience as a police officer, volunteered for this study. All participants were trained in firearms safety and familiar with shooting a department-approved semiautomatic service pistol, either a 9 mm, .40 caliber, or .45 caliber. All partici-
Pating officers passed annual department-administered physical exams and had no history of heart disease, hypertension, or musculoskeletal disease or injury. The university’s Institutional Review Board approved the study and all participants gave informed consent.

**Task and Procedure**

This study was conducted at an indoor shooting range with individually sectioned lanes. Exercise was performed on a cycle ergometer positioned in close proximity to the shooting lanes, minimizing the time between the exercise bout and the onset of the postexercise shooting trial. Heart rate monitors were worn by participants throughout the testing period. Participants used their own duty pistols, ear protection, and eye protection, and were responsible for their own pistol throughout the entire duration of the testing process. Bullets (full metal jacket/ball ammunition) and targets (human silhouette; see Figure 1) were provided for all participants.

Participants’ shooting performance was tested before and immediately after a fatiguing bout of exercise on the same day. Following the first shooting trial, participants pedaled a cycle ergometer for 4 min as a warm-up, and to allow for the estimation of maximal aerobic capacity (VO$_{2\text{max}}$) using the Astrand nomogram (Åstrand, 1960). Estimated VO$_{2\text{max}}$ was 34 ± 2 ml/kg/min. Participants then began cycling in 60 s/30 s work/rest intervals until reaching 85% of age-predicted maximum heart rate or volitional exhaustion. Participants pedaled with no resistance for the rest intervals and at 150 W (900 kpm) for the work intervals. Heart rate was recorded at the end of each work interval. Within 15 s of completing the final work interval, the participant moved to the adjacent shooting area, donned ear and eye protection, and began to fire the first postexercise round.

Both the preexercise and postexercise shooting trials consisted of three rounds of shooting, each round separated by a 15-s rest period. Heart rates were recorded directly before the start of each shooting round. Each round consisted of 5 rapid fire shots. A separate shooting lane was allotted for each of the 3 rounds; following each round, the participant moved to the next shooting lane. The participant’s back was turned toward the target during each rest period between rounds. Full magazine clips were available and ready for each round. All targets were at the same distance, 10 yards. To increase safety and prevent participants from gaining feedback from previous rounds, targets were not brought in from the 10-yard distance until after all three rounds were completed.

**Dependent Measures and Data Analysis**

To assess shooting performance, we determined shooting accuracy and shooting precision. Shooting accuracy was defined as the average of the distance of each shot in the 4-shot grouping from the center of the target (see Figure 2). Shooting precision was defined as the group shot diameter, that is, the diameter of the smallest circle that encompassed the tightest 4-shot grouping (Hoffman et al., 1992). Only the tightest 4-shots were included to eliminate the disproportionate effect of a single outlying shot. Thus, shooting precision served as a measure of shot variability, or inconsistency, and is independent of how accurate the shots were relative to the target. Heart rate served as a measure of physical exertion. Heart rates were recorded at rest, before all three preexercise trials, and during exercise to determine
when the participant had reached steady state and his target heart rate, before all three postexercise trials, and after the final trial.

Heart rates before each preexercise and postexercise trial were analyzed in a 2 (time: preexercise, postexercise) × 3 (trial) repeated-measures analyses of variance (ANOVA). The shooting accuracy (distance) and precision (diameter) data were averaged across 3 trials of 5 shots and analyzed in 2 (time: preexercise, postexercise) × 3 (trial) repeated-measures ANOVAs. Finally, we conducted linear regression analyses to determine whether heart rate would predict shooting accuracy or precision.

Figure 1 — Standard silhouette target used in shooting trials.
Results

Heart Rate

All participants exercised to volitional exhaustion, exceeding 85% of their age-predicted maximum heart rate. Average heart rate at exhaustion was 183 ± 3 bpm, which was equivalent to 96 ± 1% of the age-predicted maximum heart rate. Average heart rate for the three shooting trials was higher after exercise (164.4 bpm) than before exercise (103.6 bpm) (Figure 3, top). In addition, heart rates decreased across trials both pre- and postexercise. The main effect of time, $F(1, 7) = 100.9, p < .001, \eta^2 = .94$, was significant. The trial main effect was also significant, with $F(2, 14) = 17.82, p < .001, \eta^2 = .72$. The interaction of time and trial was not significant, $F(2, 14) < 1$.

Shooting Accuracy

Shooting accuracy was identical before and after exercise (65.4 mm) (Figure 3, middle). It also remained relatively consistent across trials both pre- and postexercise. The main effects of time, $F(1, 7) < 1$, and trial, $F(2, 14) = 1.35, p > .05$, and the interaction of time and trial, $F(2, 14) < 1$, were not significant.

Figure 2 — Representative target, illustrating measurement of shooting accuracy and precision.
Shooting Precision

Shooting precision, or consistency, was very similar before (97.3 mm) and after exercise (93.5 mm) as well, and did not change considerably across trials (Figure 3, bottom). The main effects of time, $F (1, 7) < 1$, and trial, $F (2, 14) = 1.32, p > .05$, were not significant, and there was no interaction of time and trial, $F (2, 14) = 1.16, p > .05$.

Relationship Between Heart Rate and Shooting Performance

Linear regression analyses were conducted to determine whether heart rate before or after exercise was a predictor of shooting performance. Heart rate predicted neither shooting accuracy nor precision in either phase, $F (1,46) <1, R = .0013$ and $F (1,46) <1, R = .0084$ for accuracy and precision respectively.

Discussion

The present study examined whether shooting performance in experienced police officers would be affected by physical exertion. The results showed that, even though heart rate was considerably increased (i.e., by about 60 bpm) after the exercise bout to voluntary exertion, shooting performance was not negatively affected by physical fatigue, and heart rate was not correlated with shooting performance. Both shooting accuracy (i.e., average deviation from target) and precision (consistency) were unchanged postexercise relative to preexercise.

Several factors may have mitigated any detrimental effects of exertion allowing for the maintenance of a high performance level in shooting. First, in contrast to rifle shooting, in pistol shooting, the gun is not stabilized against the body and the limb holding the pistol is able to move independently from the core of the body. This suggests that postural stability may be less important in pistol shooting than fluctuations of the arm and hand (Aalto, Pyykko, Ilmarinen, Kahkonen, & Starck, 1990; Ball, Best, & Wrigley, 2003). Even though postural sway was not measured in the current study, it seems likely that any detrimental effects of exertion on postural stability (Khanna, Kapoor, & Zutshi, 2008) would have been attenuated due to the nature of the task. Any remaining influence of postural instability on shooting performance might have been reduced by the addition of the supra-postural goal of aiming and shooting at the target (Riley, Stoffregen, Grocki, & Turvey, 1999; Stoffregen, Pagulayan, Bardy, & Hettinger, 2000; Stoffregen, Smart, Bardy, & Pagulayan, 1999). This effect is enhanced when the individual focuses externally, for example, on reducing movements of an object being touched (external focus) (McNevin & Wulf, 2002) or held (Wulf, Mercer, McNevin, & Guadagnoli, 2004; Wulf, Weigelt, Poulter, & McNevin, 2003). An external focus of attention on the intended movement outcome—such as shooting at a target—has been shown to promote movement automaticity, and an improvement in task performance (for a review, see Wulf, 2012). This contrasts with more conscious attempts at controlling body movements (internal focus). In fact, even expert performers tend to engage in conscious control processes when there are no time constraints to the initiation of an action. Conversely, when these performers are under time pressure, movement accuracy increases, presumably because time pressure promotes the use of automatic
Figure 3 — Heart rate (top), shooting accuracy (middle), and shooting precision (bottom) on pre- and postexercise trials. Shooting accuracy and shooting precision were calculated for tightest 4 shoot grouping out of 5 shots. Error bars indicated standard errors.
response capabilities (Beilock, Bertenthal, McCoy, & Carr, 2004). Thus, it appears that the combination of the time pressure imposed on participants, their level of expertise, and the presence of a supra-postural goal that promoted an external focus of attention, contributed to the maintenance of a high degree of shooting accuracy and precision despite physical exertion.

Work patterns of police officers are characterized by long periods of relatively low-level physical activity occasionally interspersed with short periods of high-intensity activity such as running, jumping, and climbing in pursuit of a suspect (Bonneau & Brown, 1995). In some cases, pursuit involves firing a weapon. Peripheral muscular fatigue provoked by short-duration, high-intensity exercise adversely affects postural stability (Dickin & Doan, 2008), and increases in postural sway and heart rate might have been expected to contribute to diminished shooting performance (Evans, Scoville, Ito, & Mello, 2003). Thus, the fitness level of the officers could have been a factor in shooting performance. However, the results of this study do not support this argument. Predicted maximal oxygen consumption (VO\textsubscript{2max}) was low to average for this age group. In addition, heart rates during the postexercise shooting trials were only modestly recovered from the postexercise peak. Together, these results indicate an average level of fitness for these officers, and suggest that fitness was not a factor in their postexercise shooting performance.

Most firearm training and qualification for police officers takes place on a shooting range under standardized conditions. However, qualification on the shooting range is not well correlated with shooting performance under pressure in the field (Oudejans, 2008). Effective shooting under pressure, as in pursuit of a suspect, requires situational awareness, quick decision making, and judgment. Consistency in form, movement, and shot location are characteristics of highly skilled and trained rapid-fire marksmen (Walmsley & Williams, 1994). While exercise-induced fatigue and physiological arousal can be distractions which negatively affect performance, expert performers in pistol shooting are able to narrow their attentional focus to the target, so as not to be distracted (Rose & Christina 1990; Vickers & Williams, 2007). It is also likely that skilled shooters spontaneously adopt an external focus (i.e., on the target), especially under time pressure. The results of this study suggest that these factors may compensate for possible detrimental effects of physical fatigue on rapid fire shooting performance in trained police officers. In future studies, it would be interesting to explore to what extent physical fatigue affects shooting performance at different skill levels. Furthermore, given the demonstrated performance and learning benefits of skill practice with an external focus of attention (see Wulf, 2012), firearm training for police officers could possibly be further enhanced, or sped up, by incorporating instructional methods that promote the adoption of external foci.

References


