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Relationship between efficiency of pistol shooting and selected physical-physiological parameters of police

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Abstract

Purpose – The purpose of this study is to investigate the relationship between selected physical-physiological parameters and efficiency of pistol shooting.

Design/methodology/approach – In all, 237 male volunteers, studying at a Turkish Police Academy within the age range of 19-20 years old were investigated. The physical fitness levels were evaluated by valid and reliable test batteries. The efficiency of pistol shooting was evaluated by the total points of the bullets which hit the target from 10 m.

Findings – Significant differences were found between the sets of students according to shot accuracy groups for wrist circumference, biceps circumference, femur diameter, hand grip strength, flexibility, aerobic capacity, reaction time, balance, coordination, state anxiety level, anxiety variability, average heart rate, maximal heart rate and heart rate changes. The correlation coefficient between the pistol shooting result and change in heart rate, anxiety variability, mean heart rate during shooting, coordination, state anxiety, maximal heart rate during shooting, balance, hand-grip strength, biceps circumference, femur diameter, wrist circumference and flexibility was significant.

Practical implications – This research identified parameters which were important in profiling a good shooter. In addition, this result could be used for choosing marksmen and guiding shooting training for athletes and police in which shooting skills are important. It was reported that joining simple field physical fitness tests and simple devices such as heart rate polar meters may have an advantage in selecting good shooters. These would save police departments both time and money.

Originality value – This is the most comprehensive study to date which has evaluated physical fitness in relation to shooting efficiency.

Keywords Police, Anxiety level, Efficiency of pistol shooting, Performance measure, Physical fitness, Shooting

Paper type Research paper

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Introduction

A weapon is described as anything used, designed to be used or intended for use in causing death or injury to a person, or for the purpose of threatening or intimidating a person and, includes without limitation a firearm (Code, 1985). Bussard and Wormley (2006) defined a firearm as an assembly of a barrel and an action from which a projectile is propelled through the deflagration (rapid burning) of a propellant (gunpowder).

Since the duty of law enforcement is a high-risk profession and often accompanied by high levels of acute stress, personnel have to endure adverse conditions that might arise from this risk, and have to expend very high physical efforts and attentional control when encountering crime (Sztajnkrycer *et al.*, 2007; Vrij and Dingemans, 1996; Vrij *et al.*, 1994; Anderson *et al.*, 2002; Oudejans and Nieuwenhuys, 2009). Because of this reality it may be necessary for officers to be armed for their own safety or for the protection of members of the public. Moreover, police officers may suddenly find themselves in a life-threatening situation (Anderson *et al.*, 2002). Despite the relatively low incidence of such events (Morrison and Vila, 1998), police officers must be prepared for these situations so that they can respond in an appropriate and safe way (Oudejans, 2008). The usage of firearms by the police is covered by statute, policy and common law. Police firearms training actually teaches the use and discharge of firearms to remove the threat rather than to kill (Rogers, 2003). Consequently, policeman should always be physically, physiologically and mentally fit, in compliance with their work and as stated above, for the safety and peace of the community.

While police officers' shooting performances are good in handgun training programmes, their performances decrease in high anxiety conditions such as in the line of duty (Oudejans, 2008; Nieuwenhuys and Oudejans, 2010; Morrison and Vila, 1998). Current studies show that training with anxiety improves handgun shooting performance under stressful circumstances (Oudejans, 2008; Oudejans and Pijpers, 2009; Nieuwenhuys and Oudejans, 2011).

Mental and emotional states directly affect the autonomic nervous system. Psychological states and processes can impact dramatically on dynamic autonomic control of the heart (Berntson and Cacioppo, 2004). Many of the Institute of Heart Math's research studies have examined the influence of emotions on the autonomic nervous system utilising the analysis of heart-rate variability or heart rhythms, which serve as a dynamic window into autonomic function and balance. The nervous system links the heart and the brain. Heart-rate variability is due to the interaction between the two branches of the nervous system and the afferent signals sent from the heart to the brain (McCraty *et al.*, 2001). Stressors are often associated with an increase in sympathetic cardiac control, a decrease in parasympathetic control or both (Berntson and Cacioppo, 2004). Many studies indicate that anxiety and autonomic control document complex links between behavioural and cardiovascular systems (Berntson *et al.*, 1998). Previous research on competitive closed-skill sports showed an association between a heart rate decrement and athletes' preparatory performance. There is a consensus that cardiac cycle and the slowing of heart rate in sports like golf, shooting and archery facilitates athletes' attentional focusing, and is associated with successful performance (Konttinen *et al.*, 1998; Wang and Landers, 1986; Helin *et al.*, 1987). Tremor size has a demonstrable inverse correlation with shooting performance. A component of tremor size is the activity of the heart and, to some extent, respiratory movements (Lakie, 2010). Although β blockers can suppress tremor size and have been shown to improve shooting performance, Kruse *et al.* (1986) found no correlation between the shooting improvement and changes in the cardiovascular variables. Such drugs are banned in target shooting, and any level detected in the blood during performance is a contravention (WADA, 2012).

One of the segments of special physical fitness and technical and tactical training of law enforcement is the capability to efficiently master complex situations requiring the use of weapons. Some studies indicate that the correlation coefficient between the result of the pistol shooting and selected physical fitness variables were significant (Anderson and Plecas, 2000; Vučković and Dopsaj, 2007). Kayıhan *et al.* (2010) showed that the values for some physical fitness parameters can be used as an indirect testing procedure for predicting efficiency of pistol shooting in police officers.

In brief, shooting is an example of an activity which requires consistency and accuracy (Lakie, 2010). Shooting ability is affected by many internal and external factors. There is little knowledge about the physiological and psychological limitations of shooting ability.

Therefore, the aim of this study was to investigate the relationship between selected physical-physiological parameters and efficiency of pistol shooting.

Methods

Subjects

In this study, 237 male volunteers, studying at a Turkish Police Academy within the age range of 19-20 years old were investigated. Their mean age, height, body weight, body mass index (BMI) and body fat rate (per cent) were 20.40 ± 0.76 years, 1.77 ± 0.05 m, 70.44 ± 7.57 kg, 22.40 ± 2.12 kg/m^2 and 14.96 ± 5.46, respectively. This study was approved by The Research Ethics Committee of the Ankara University Medical Faculty and the Health Department of the Turkish National Police. Participants were informed about the possible risks of the study and gave informed consent to participate in this study.

Body composition and anthropometric measurements

On the days of assessment, participants were asked to refrain from exercise and to have not eaten a heavy meal (a meal that would typically constitute breakfast, lunch or dinner) three hours prior to measurement. Height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg), without shoes, were measured for each participant using a portable stadiometer (Holtain, UK) and physician's scale (Tanita TBF 401 A, Japan), respectively. BMI was calculated using the formula: weight (kg) divided by height (m) squared. Skinfold thicknesses were measured from nine different anatomical regions (biceps, triceps, subscapular, midaxillar, pectoral, abdominal, thigh, suprailiac and calf) with a Holtain skinfold caliper which applied a pressure of 10 g/mm^2 with an accuracy of ± 2 mm at the dominant side of the body (Going *et al.*, 2001; Heyward, 2006). Gulick anthropometric tape (Holtain, UK) with an accuracy of ± 1 mm was used to measure the circumference of extremities. Diametric measurements were determined by Harpenden calipers (Holtain, UK) with an accuracy of ± 1 mm. The percentage of body fat was determined by the Jackson and Pollock formula (Jackson and Pollock, 1978).

Aerobic performance evaluation (the 20-metre shuttle run test (20-MST))

The aerobic capacities of the policemen were evaluated by the 20-MST. The 20-MST is a multistage test published by Léger and Lambert (1982) and revised in 1988 (Léger *et al.*, 1988). It involves running back and forth across a 20-metre course in time to music played from a tape or CD. Beeps on the sound track indicate when a person should reach the ends of the course. The test begins at a slow pace, and each minute the pace increases. A participant continued running until the pace could no longer be maintained. The test was stopped if the subject failed to reach the line for two consecutive ends.

The equation of Léger and Lambert (1982) was used for the prediction of aerobic capacity from the 20-MST. The equation uses the highest speed (km/hr) for the prediction ($R = 0.84$, SEE = 5.4 ml/kg/min):

$$VO_{2\,\max} = 5.857 \times \textit{The Maximal Speed}\ (\text{km/h}) - 19.458$$

Muscle strength and endurance measurements

Muscular handgrip strength was assessed using a Takei TKK 5101 handgrip dynamometer (Takei Scientific Instruments, Tokyo, Japan). The test was performed by the dominant side in the sitting position with the shoulder of the tested arm adducted, the elbow flexed at 90°, on the other hand the forearm and wrist were set in neutral position. The testing protocol consisted of three maximal isometric contractions for 5s, on dominant hands, with a rest period of at least 60s and the highest value (kg) was used for determination of maximal grip strength. The subjects were instructed to squeeze the dynamometer as hard as possible. Muscular endurance was assessed using the curl up test. In this test the subjects laid on their back with the arms fully extended with fingers resting on the legs and pointing towards the knees. The subjects curled up slowly; sliding their fingers along their legs until their fingertips touched their knees, then back down again, until their head touched the mat. The total number of curl ups was recorded which students were able to complete in 30 and 60s (Tritschler, 2000).

Flexibility measurement

Flexibility was evaluated by the sit and reach test which is the most common flexibility test used in health related fitness test batteries. The subjects sat with their feet approximately hip-width against the testing box. They kept their knees extended and placed the right hand over the left, and slowly reached forward as far as they could by sliding their hands along the measuring board. Reaches short of the toes were recorded as negative forward reach scores, and reaches beyond the toes were recorded as positive forward reach scores in centimetre to the nearest 0.5 cm using the scale on the box (Wells and Dillon, 1952).

Reaction time evaluation

The Newtest 1000 Reaction time device was used for measuring visual reaction time. An auditory stimulus was presented to which the participant was asked to press a button on the Newtest device ten times. The participant's fingertip was about 1 cm from the key. The longest and shortest reaction times were removed from the analyses.

Balance assessment

The Stork Balance Standing Test was used to assess the ability to balance on the ball of the foot. Participants were asked to remove the shoes and place the hands on the hips, then position the non-supporting foot against the inside knee of the supporting leg. The subjects were given one minute to practice the balance. The subjects raised the heel to balance on the ball of the foot. The stopwatch was started as the heel is raised from the floor. The stopwatch was stopped when the athlete's right heel touched the ground or the left foot moved away from the right kneecap. The total time in seconds was recorded. The score was the best of three attempts (McCurdy and Langford, 2006; Tritschler, 2000).

Coordination assessment

The Alternate Hand Wall Toss Test was used to measure hand-eye coordination. A mark was placed at a distance of 2 m from the wall. The person stood behind the line facing the wall. The ball was thrown from one hand in an underarm action against the wall, and was attempted to be caught with the opposite hand. The ball was then thrown back against the wall and caught with the initial hand. The test continued for a 30-s period. The number of successful catches in a 30-s period was recorded (Beashel *et al.*, 2001).

Shot accuracy

All test procedures were conducted in accordance with the shotgun safety regulations of the International Shooting Sport Federation. Subjects shot with 9.0 mm calibre service pistols (CZ 75B) at a distance of 10 m, and the programme consisted of ten shots within 20 min. The efficiency of pistol shooting was evaluated by the total points of the bullets which hit the ten-ring target from 10 m. There were some restrictions on the pistol, and it was operated by one hand only from a standing position. There was no support for the arm or wrist (Federation, 2013).

Heart rate recording

The Polar Team2 Pro (Polar Electro, OY, Kempele, Finland) device for heart rate was used as the data collection tool. Participants wore heart rate monitors five minutes before and after shooting and during shooting. Heart rate was recorded in 5-s intervals by short-range radio telemetry (PolarTeam2 which is composed of a chest strap, a sensor and a transmitter). Resting heart rate before shooting, average and maximal heart rate during shooting were recorded.

Anxiety assessment

The State-Trait Anxiety Inventory (STAI) was used to assess anxiety. The form had 20 questions for assessing trait anxiety and 20 questions for assessing state anxiety. Participants fulfilled state anxiety forms just before shooting sessions and trait anxiety forms when they were relaxing (Spielberger *et al.*, 1970).

Statistical analysis

Means and standard deviations are given as descriptive statistics. The efficiency of pistol shooting was grouped (low, moderate and high) according to K-means clusters of scores. The One-way ANOVA test was used for comparing means according to the shooting level groups. The correlations between the results were made using the Pearson Correlation Analysis. The method of multiple regression analysis was used in order to determine the linear association between the set of predictor variables and the dependent variable. For all statistics the significance level was set at $p < 0.05$. Data were analysed using the Statistical Package for Social Sciences (SPSS) MS Windows Release 13.0.

Results

Table I shows an overview of the means and standard deviations of all dependent variables in the low, moderate and high groups according to shot accuracy.

Variable	Low ($n=61$) M	SD	Moderate ($n=111$) M	SD	High ($n=65$) M	SD
Shot accuracy (%)	56.48	4.08	72.65	3.78	86.72	4.09**
Physical characteristics						
Age (years)	20.44	0.72	20.42	0.72	20.31	0.86
Body weight (kg)	70.54	7.26	70.11	7.40	70.91	8.19
Body height (m)	1.78	0.05	1.77	0.051	1.78	0.052
BMI (kg/m^2)	22.2	1.83	22.4	22.7	2.25	21.2
Body composition						
Wrist circumference (cm)	17.16	1.23	17.17	1.26	17.79	1.23*
Biceps circumference (cm)	26.21	2.15	26.83	2.36	27.60	1.94*
Calf circumference (cm)	35.01	2.42	35.06	2.79	35.77	3.04
Humerus diameter (cm)	11.94	0.39	11.86	0.31	11.92	0.29
Femur diameter (cm)	15.00	0.54	14.79	0.44	14.74	0.41*
Thigh skinfold thickness (mm)	13.25	4.68	12.00	4.13	12.31	3.71
Pectoral skinfold thickness (mm)	7.86	2.92	7.67	2.41	7.98	2.53
Abdominal skinfold thickness (mm)	14.44	5.29	15.11	6.17	14.96	5.46
Muscular fitness						
Muscular endurance (curl up) 30 s	27.90	3.46	28.43	3.39	27.36	3.95
Muscular endurance (curl up) 60s	51.95	6.21	52.75	6.10	51.18	6.97
Muscular strength (hand grip) (kg)	46.37	4.22	46.09	3.46	48.87	4.07**
Flexibility (cm)	25.70	5.60	28.10	5.96	28.52	5.44*
Aerobic capacity (ml/kg/min)	49.40	2.31	49.50	2.55	49.29	2.27
Reaction time (ms)	448.11	35.98	456.90	48.01	436.42	43.95*
Balance (s)	25.30	14.04	31.60	13.36	37.05	13.59**
Coordination (number)	23.20	5.735	25.40	5.906	29.49	7.129**
Anxiety						
State anxiety	46.92	3.95	44.44	4.33	42.18	4.78**
Trait anxiety	38.30	3.01	38.63	3.10	39.12	3.19
Change in anxiety	8.62	4.20	5.81	2.99	3.06	3.52**
Heart rate (pulse/min)						
Resting heart rate	73.11	6.99	73.29	6.46	73.69	6.16
Average heart rate	117.30	17.98	103.32	13.95	94.85	15.49**
Maximal heart rate	144.39	18.14	133.52	19.45	127.83	19.36**
Change in heart rate (during shooting)	44.18	16.66	30.03	14.22	21.15	14.83**

Notes: $^{*}p<0.05$; $^{**}p<0.01$

Table I. The means and standard deviations of all dependent variables in the low, moderate and high groups according to shot accuracy

Although significant differences ($p<0.05$) were found between the groups of the students according to shot accuracy groups for wrist circumference, biceps circumference, femur diameter, hand grip strength, flexibility, aerobic capacity, reaction time, balance, coordination, state anxiety level, anxiety variability, average heart rate, maximal heart rate and heart rate changes (during shooting), no obvious differences ($p>0.05$) were found for age, height, weight, body mass index, calf circumference, humerus diameter, femur diameter, skinfold thicknesses of pectoral, thigh and abdominal, muscular endurance, aerobic capacity, trait anxiety level and resting heart rate (Table I).

According to Pearson product-moment correlation analysis, the correlation coefficient between the result of pistol shooting (shot accuracy) and the change in heart rate ($r=-0.518$, $p<0.01$), change in anxiety ($r=-0.518$, $p<0.01$), mean heart rate during shooting ($r=-0.499$, $p<0.01$), coordination ($r=0.376$, $p<0.01$), state anxiety ($r=-0.365$, $p<0.01$), maximal heart rate during shooting ($r=-0.327$, $p<0.01$), balance ($r=0.312$, $p<0.01$), hand-grip strength ($r=0.242$, $p<0.01$), biceps circumference ($r = 0.240$, $p < 0.01$), femur diameter ($r = -0.209$, $p < 0.01$), wrist circumference ($r = 0.202$, $p < 0.01$) and flexibility ($r = 0.189$, $p < 0.05$) were significant. There was no significant correlation between shot accuracy (per cent) and physical characteristics, calf and humerus diameter, thigh, pectoral and abdominal skinfold thicknesses, aerobic capacity, resting heart rate, trait anxiety, reaction time and muscular endurance (Table II).

Table III shows the results from multiple regressions analysis. The results show that the separated set of 12 predicting variables statistically and significantly describe the criterion variable. The model explains 49.99 per cent of criterion variability with a standard estimation error of ± 8.524 per cent of shooting efficiency.

An equation was designed in which the coefficient of determination equal to 0.499 indicated that approximately 49.9 per cent of the variation in shooting performance could be explained by the relationship with 12 physical and physiological parameters.

	Total ($n = 237$)		
Variable	*M*	SD	Pearson's correlation
Shot accuracy (%)	72.35	11.72	
Physical characteristics			
Age (years)	20.40	0.76	−0.02
Body weight (kg)	70.44	7.57	0.005
Body height (m)	1.77	0.051	−0.055
BMI (kg/m^2)	2.24	2.12	0.037
Body composition			
Wrist circumference (cm)	17.34	1.27	0.202**
Biceps circumference (cm)	26.88	2.25	0.240**
Calf circumference (cm)	35.24	2.78	0.094
Humerus diameter (cm)	11.90	0.33	−0.030
Femur diameter (cm)	14.83	0.47	−0.209**
Thigh ST (mm)	12.41	4.18	−0.099
Pectoral ST (mm)	7.80	2.57	−0.016
Abdominal ST (mm)	14.90	5.74	0.003
Flexibility (cm)	27.60	5.82	0.189*
Aerobic capacity (ml/kg/min)	49.41	2.41	0.012
Muscular fitness			
Curl up (30 s)	28.00	3.58	−0.040
Curl up (60 s)	52.11	6.38	−0.022
Hand grip (kg)	46.93	4.01	0.242**
Reaction time (ms)	449.02	44.73	0.109
Balance (s)	31.47	13.59	0.312**
Coordination (number)	25.95	6.20	0.376**
Anxiety			
State anxiety	44.46	4.68	−0.365**
Trait anxiety	38.68	3.11	0.120
Change in anxiety	5.78	3.63	−0.518**
Heart rate (pulse/min)			
Resting heart rate	73.35	6.50	0.029
Average heart rate	104.59	17.51	−0.499**
Maximal heart rate	134.76	19.99	−0.327**
Change in heart rate (During shooting)	31.24	14.36	−0.518**

Notes: *$p < 0.05$; **$p < 0.01$

Table II. Correlation (P-Pearson) between efficiency of pistol shooting and selected physical-physiological parameters

Table III.
Multiple regression analysis of the defined model of mathematical regression equation

Model	Non-standardized coefficients b	SE	Standardized coefficients β	t	Sig.
Variables	134.377	22.038		6.097	0.000
Change in heart rate	−0.156	0.09	−0.229	−1.726	0.086
Change in anxiety	−0.893	0.23	−0.306	−3.871	0.000
Average heart rate	−0.070	0.09	−0.105	−0.789	0.431
Coordination	0.385	0.15	0.218	2.504	0.013
State anxiety	−0.081	0.19	−0.032	−0.432	0.666
Maximal heart rate	0.010	0.05	0.018	0.208	0.835
Balance	0.011	0.06	0.013	0.179	0.858
Hand grip	0.117	0.19	0.040	0.626	0.532
Biceps circumference	0.975	0.33	0.187	2.941	0.004
Femur circumference	−4.883	1.242	−0.196	−3.931	0.000
Wrist circumference	−0.624	0.677	−0.068	−0.921	0.358
Flexibility	−0.045	0.103	−0.022	−0.433	0.666
Model	R	R^2	Adjusted R^2	SE of estimate	
1	0.706[a]	0.499*	0.472	8.521	

Notes: [a]Predictors which are used in regression analysis which are significant at $p = 0.000$. Dependent variable: shooting performance. $*p < 0.05$

The model of the mathematical regression equation which is given below is defined for the prediction of shooting performance:

$$\begin{aligned}\text{Estimated shooting performance score} =\; & 134.377 + (-0.156\times\text{Change in heart rate}) \\ & +(-0.893\times\text{Change in anxiety}) + (-0.070\times\text{Average heart rate}) \\ & +(0.385\times\text{Coordination}) + (-0.081\times\text{State anxiety}) \\ & +(0.0010\times\text{Maximum heart rate}) + (0.011 + \text{Balance}) \\ & +(0.117\times\text{Hand grip strength}) + (0.975\times\text{Biceps circumference}) \\ & +(-4.883\times\text{Femur circumference}) + (-0.624\times\text{Wrist circumference}) \\ & +(-0.045\times\text{Flexibility}) + 8.521\ (p\ \text{lt};0.01.\ r = 0.706.\ \mathrm{R}^2 = 0.499)\end{aligned}$$

Discussion

In agreement with previous research on sharpshooting performance, we discuss whether there are any grounds for arguing that physical and physiological parameters patterns are associated with the efficiency of shooting performance. The principal results of the present study demonstrated that there were significant relationships between shooting performance and physical fitness parameters namely coordination, balance, muscular strength (hand grip) and flexibility. Shooting is classified as a member of one of the precision sports by the NCCP. According to the NCCP, shooting performance is highly affected by motor abilities such as coordination and balance and moderately affected by flexibility and maximal strength (CAC, 2003).

According to shooting coaches and athletes, good postural balance is a vital component of a successful shooting performance. Previous studies have also supported this view (Aalto *et al.*, 1990; Zatsiorsky and Aktov, 1990; Era *et al.*, 1996; Konttinen *et al.*, 1998; Mononen *et al.*, 2007). The study of Mononen *et al.* (2007) examined the relationships ($r = 0.33$) between shooting accuracy and postural balance. The results of the Mononen *et al.* (2007) also suggested that postural balance is related to the shooting accuracy both directly and indirectly through rifle stability. Similar to the findings of the earlier studies, the results of the present study, indicate that postural balance is related to shooting accuracy ($r = 0.312$).

Learning how to shoot requires discipline, self-control, hand-eye coordination and concentration (NSSF, 2009). Law enforcement officers must have excellent visual skills and hand-eye coordination in order to be observant and fulfil the demands of their jobs. Police officers' internal coordinate systems must match the coordinates in the real world for good shooting performance (Pannone and Dawkins, 2006). Shooting is a motor task that demands a high level of hand-eye coordination (Mason *et al.*, 1989; Zatsiorsky and Aktov, 1990; Konttinen *et al.*, 1998; Mononen *et al.*, 2003; Ball *et al.*, 2003). The findings showed that the police officers' coordination levels assessed by the Alternate Hand Wall Toss were related to shooting accuracy. In line with earlier findings, the present result implies that good coordination is necessary for superior shooting performance among police. The Alternate Hand Wall Toss test which is a simple field test can be useful for the selection of good shooters.

The stability of the gun in the shooting position has been associated with the size of the grip of the gun. Muscles of the forearm dictate the strength of the hand. These muscles control the grip on a gun and the trigger pull (Anderson and Plecas, 2000; Atkins, 1993). For this reason, hand grip, humerus diameter, biceps and wrist circumference were measured in the present study as an indication of forearm muscle strength and mass, while grip strength of the dominant hand was measured as direct indicators of static muscular strength. Our results show that there were significant differences and correlations ($p < 0.05$) between wrist circumference, biceps circumference, hand grip strength and shooting performance. No study can be found which assesses directly the relationship between shooting performance and anthropometric measurements. However, similar to our indirect results, Anderson and Plecas (2000) found significant correlations between shooting score, dominant grip strength ($r = 0.38$) and forearm girth ($r = 0.28$). Moreover, Kayıhan *et al.* (2010) indicated that the correlation coefficient between the result of the pistol shooting achievement and the biceps circumference ($r = 0.177$, $p < 0.001$) and calf circumference ($r = 0.146$, $p < 0.001$) were significant. Kılınç *et al.* (2010) also found significant relationships ($p < 0.05$) between the shooting performances of female archers and the arm and forearm circumference. Earlier studies revealed a positive association between handgrip strength and handgun qualifying score (Copay and Charles, 2001; Rodd *et al.*, 2010; Charles and Copay, 2003). Rodd *et al.* (2010) generated a prediction equation in which the coefficient of determination indicated that approximately 7.1 per cent of the variation ($p = 0.008$ with and R^2 of 0.071) to predict handgun score was based on handgrip strength. Similarly our results showed that approximately 5.9 per cent of the variation ($p = 0.000$ with $r = 0.242$ and R^2 of 0.059) in shooting performance could be explained by the hand grip strength.

The results of the present study showed that the shooting efficiency was 72.35 per cent of the total points of the bullets which hit the target from 10 m. Similarly, Vučković *et al.* (2008) showed that the shooting efficiency was 73.92 per cent when ten bullets were fired at a circular target from a distance of 10 m. Multiple regression analysis of the data of our present study show that 49.9 per cent of shooting performance could be explained with statistical significance by the model of 12 selected physical and physiological predicting parameters. Vučković and Dopsaj (2007) show that 11.79 per cent of the efficiency of shooting from hand fire-arms depends, in this case, on the motor abilities represented by physical characteristics of contractile abilities of the tested muscle groups, locomotion speed, aerobic fitness, general energetic efficiency of body functions under effort and specific dexterity. Our present equation can explain more about shooting performance than Vučković and Dopsaj (2007) because more variables which are possibly related with shooting performance such as heart rate, anxiety level and all health-related and sport-related physical fitness parameters were analysed in our study.

Previous research on shooting sports showed an association between a heart rate decrement and shooting performance (Salazar *et al.*, 1990; Wang and Landers, 1986, Kolayiş and Mimaroğlu, 2008, Landers *et al.*, 1994). Oudejans (2008) showed that shooting performance was significantly worse under high pressure compared to low pressure. Oudejans (2008) showed that on average heart rates tended to be somewhat higher in the high-pressure condition (mean = 115.9, SD = 12.48) compared to the low-pressure condition (mean = 114.1, SD = 12.93). Our results show that the change in heart rate ($r = -0.518$, $p < 0.01$), mean heart rate during shooting ($r = -0.499$, $p < 0.01$) and maximal heart rate during shooting ($r = -0.327$, $p < 0.01$) were associated with shooting performance. However, some studies have shown that there is no correlation between shooting performance and changes in the cardiovascular variables (i.e. changes of heart rate and systolic blood pressure). Helin *et al.* (1987) showed that there is a significant relationship between shooting performance and the timing of triggering with elite and beginner shooters. The elite level and beginner shooters obtained better scores when they triggered during the diastolic phase of cardiac cycle. Kruse *et al.* (1986) showed that in a double-blind cross-over study of 33 marksmen the adrenergic β1-receptor blocker, metoprolol, significantly improved (13.4 per cent of possible improvement as an average) the pistol shooting performance compared with placebo. Kruse *et al.* (1986) explained the shooting improvement because of the effect of metoprolol on hand tremor. Tremor size has a demonstrable inverse correlation with shooting performance (Lakie, 2010).

Zhuang *et al.* (2008) suggest that during the shooting match, under a variety of external and internal psychological stressors, the activation of sympathetic nerve of the autonomic nervous system and heart rate in shooters are increased significantly from 66 ± 7 beats/min to 82 ± 12 beats/min whereas the activation of parasympathetic branch is withdrawn (Zhuang *et al.*, 2008). Our results support earlier findings that showed significant differences between resting heart rate before shooting and average heart rate during shooting (from 73.35 ± 6.59 to 104.59 ± 17.51 beats/min).

Police work requires the ability to perform under pressure (Anderson *et al.*, 2002; Le Scanff and Taugis, 2002; Shipley and Baranski, 2002; Oudejans, 2008). However, most of the firearms training and shooting tests of ordinary police officers take place at the shooting range with stationary non-threatening targets (Morrison and Vila, 1998). Shooting performances decrease in high-anxiety conditions such as in the line of duty (Oudejans, 2008; Nieuwenhuys and Oudejans, 2010; Morrison and Vila, 1998). Nieuwenhuys and Oudejans (2011) investigated the short- and long-term effects of training with anxiety on police officers' shooting behaviour under pressure. At the pre-test of their study, the shot accuracy showed a strong and significant decrease under anxiety, with hit percentages dropping from about 90 per cent or more in the low-anxiety condition to 80 per cent or less in the high-anxiety condition. Similarly, our present study showed that significant differences ($p < 0.05$) were found for state anxiety level and change in anxiety during shooting between the groups of the students according to shot accuracy groups. While the low shot accuracy group's anxiety level was 46.92 ± 3.95, anxiety levels were 44.44 ± 4.33 and 42.18 ± 4.78 in the moderate and high shot accuracy groups, respectively. Moreover, similar to previous studies (Oudejans, 2008; Oudejans and Pijpers, 2009; Eysenck *et al.*, 2007;

Nieuwenhuys and Oudejans, 2011); no obvious significant differences ($p > 0.05$) were found for trait anxiety level.

Practical applications

In general, the results of our study have supported previous studies and produced the profile of a good shooter. A significant amount of time and money is spent by police departments on the selection and training of new law enforcement officers. According to the findings of the present study, simple field physical fitness tests such as the Alternate Hand Wall Toss test, the Stork Balance Standing Test and simple devices such as heart rate polar meters could be used as part of the selection process to pre-qualify officers seeking to handle firearms but should not be used as sole indicators of a good shooter. These would save police departments both time and money. These results could be useful for choosing police for Special Forces, Public Security, Anti-Terror and Smuggling branches in which shooting skills are important. In addition, we suggest that this result could be used for choosing marksmen and guiding shooting training. In future studies, it is of interest to examine whether providing special training programs could aid law enforcement officers in improving the physical and physiological parameters which are related with shooting accuracy. Our findings showed that there are significant relationships between selected physical-physiological parameters and efficiency of pistol shooting. However, regular police training largely neglects the role of psychological factors. Future studies should attempt to investigate the effects of self-regulation and anxiety training programs which can be useful for decreasing heart rate and anxiety level on police officers' shooting performance.

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