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Originales

VARIABLES ASSOCIATED WITH SHOOTING PERFORMANCE AT REST AND AFTER PHYSICAL EFFORT IN POLICE OFFICERS

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ABSTRACT

Objectives: We aimed to evaluate the correlation between anthropometric, cardiovascular, and aerobic fitness variables with shooting performance at rest and after physical exertion in police officers which is important for police preparation.

Methods: The sample consisted of 15 male police officers. In the first session, systolic blood pressure (SBP), resting heart rate (HR_{rest}), peak oxygen consumption (VO_{2peak}), and waist-to-hip ratio (WHR) were evaluated. In the second session, shooting performance was evaluated before (SP_{pre}) and after (SP_{post}) the physical effort by the scored points in five shots at a scored target, and shooting time (ST_{pre} and ST_{post}). Next, officers ran ~300 m on a course designed to simulate a foot chase to make the shortest time possible, while we recorded the elapsed running time (RT) and the heart rate (HR). Pearson's correlation test was used, adopting P<0.05.

Results: At rest, there was a negative correlation between SP_{pre} and age (r=-0,71; P<0.01) and SBP (r=-0.53, P<0.04). The results suggest that age and cardiovascular variables are differently associated with shooting performance in police officers.

Conclusion: Age and SBP may be negatively related to resting shooting performance in police officers. The physical fitness of the sample may have been a factor to be considered for not observing these correlations. In this way, good physical conditioning may have influenced shooting performance, which impacts police preparation, given the importance of acting on all factors that minimize damage when using firearms and increase their effective use.

Keywords: Physical effort; accuracy; shooting.

VARIABLES ASOCIADAS CON EL RENDIMIENTO DE TIRO EN REPOSO Y DESPUÉS DEL ESFUERZO FÍSICO EN OFICIALES DE POLICÍA

RESUMEN

Objetivos: Nuestro objetivo fue evaluar la correlación entre las variables antropométricas, cardiovasculares y de aptitud aeróbica con el rendimiento de tiro en reposo y después del esfuerzo físico en oficiales de policía, lo cual es importante para la preparación policial.

Métodos: La muestra estuvo compuesta por 15 oficiales de policía varones. En la primera sesión, se evaluaron la presión arterial sistólica (PAS), la frecuencia cardíaca en reposo (FCreposo), el consumo máximo de oxígeno (VO2pico) y la relación cintura-cadera (CCA). En la segunda sesión, se evaluó el rendimiento de tiro antes (SPpre) y después (SPpost) del esfuerzo físico mediante los puntos obtenidos en cinco tiros a un objetivo puntuado y el tiempo de tiro (STpre y STpost). A continuación, los oficiales corrieron ~300 m en un recorrido diseñado para simular una persecución a pie para hacer el menor tiempo posible, mientras registrábamos el tiempo de carrera transcurrido (RT) y la frecuencia cardíaca (FC). Se utilizó la prueba de correlación de Pearson, adoptando P < 0,05.

Resultados: En reposo, se encontró una correlación negativa entre la SPpre y la edad (r=-0,71; P<0,01) y la PAS (r=-0,53, P<0,04). Los resultados sugieren que la edad y las variables cardiovasculares se asocian de forma diferente con el rendimiento de tiro en policías.

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Conclusión: La edad y la PAS pueden estar relacionadas negativamente con el rendimiento de tiro en reposo en policías. La condición física de la muestra puede haber sido un factor a considerar para no observar estas correlaciones. De esta forma, un buen acondicionamiento físico puede haber influido en el rendimiento de tiro, lo que repercute en la preparación policial, dada la importancia de actuar sobre todos los factores que minimicen el daño al utilizar armas de fuego y aumenten su uso efectivo.

Palabras clave: Esfuerzo físico; precisión; tiro.

VARIÁVEIS ASSOCIADAS AO DESEMPENHO DE TIRO EM REPOUSO E APÓS ESFORÇO FÍSICO EM POLICIAIS

RESUMO

Objetivos: Nosso objetivo foi avaliar a correlação entre variáveis antropométricas, cardiovasculares e de aptidão aeróbica com o desempenho de tiro em repouso e após esforço físico em policiais, o que é importante para a preparação policial.

Métodos: A amostra foi composta por 15 policiais do sexo masculino. Na primeira sessão, foram avaliadas a pressão arterial sistólica (PAS), a frequência cardíaca em repouso (FCrepouso), o consumo máximo de oxigênio (VO2pico) e a relação cintura-quadril (RCQ). Na segunda sessão, o desempenho de tiro foi avaliado antes (SPpré) e depois (SPpós) do esforço físico pelos pontos marcados em cinco tiros em um alvo marcado e o tempo de tiro (STpré e STpós). Em seguida, os policiais correram ~300 m em um percurso projetado para simular uma perseguição a pé para fazer o menor tempo possível, enquanto registramos o tempo de corrida decorrido (TR) e a frequência cardíaca (FC). O teste de correlação de Pearson foi usado, adotando P<0,05.

Resultados: Em repouso, houve correlação negativa entre SPpre e idade (r=-0,71; P<0,01) e PAS (r=-0,53, P<0,04). Os resultados sugerem que idade e variáveis cardiovasculares estão diferentemente associadas ao desempenho de tiro em policiais.

Conclusão: Idade e PAS podem estar negativamente relacionadas ao desempenho de tiro em repouso em policiais. A aptidão física da amostra pode ter sido um fator a ser considerado para não observar essas correlações. Dessa forma, um bom condicionamento físico pode ter influenciado o desempenho de tiro, o que impacta no preparo policial, dada a importância de atuar em todos os fatores que minimizem os danos ao usar armas de fogo e aumentem seu uso efetivo.

Palavras-chave: Esforço físico; precisão; tiro.

INTRODUCTION

The primary duty of the police is ensuring public safety through direct contact with criminal actions, involving high risks. Firearm use is allowed in extreme situations to protect life with minimal harm. Muscle fatigue from physical exertion, like foot pursuits, can compromise[1] shooting accuracy by affecting stability and postural balance, which are crucial for performance.

Shooting is a precision task that requires specific physiological adjustments and its performance may be related to the autonomic nervous system modulation since an excessive sympathetic response is harmful to cognitive and psychomotor tasks such as aiming[2] which requires the ability to narrow focus and sustained attention[3]. Cardiac autonomic responses reflect nervous system modulation and distinguish better and worse triggers[4]. In a simulated school shooting, Strahler and Ziegert[5] found an increase in sympathetic activity immediately before the shooting, which tends to be greater in a situation of real danger. Increased sympathetic modulation increases tremors[6], which impairs shooting performance[7,8]. Tremors can be caused by muscle fatigue[9], muscle glycogen depletion[10], increased heart rate (HR)[6], and increased systolic blood pressure (SBP)[11]. Therefore, it becomes important to reduce tremors as much as possible.

Performing physical exertion immediately before shooting can increase tremors due to muscle fatigue[6] and impair performance[8,9]. However, conflicting results have been presented in the literature, with studies showing no negative effect of physical exertion on shooting performance[3,12] or even finding performance improvement after exercise[13]. Gil-Cosano et al.[14] verified that the performance of a shooting test after walking around carrying military equipment worsened shooting performance, attributing to fatigue as the determining factor of the negative impact on accuracy. In this sense, aerobic power is one measure of physical fitness that may be related to shooting performance due to physiological adaptations related to aerobic exercise training, such as greater parasympathetic autonomic modulation, lower HR at rest and during submaximal exercise and greater maximum exercise capacity, which would results in less disturbance in physiological variables in submaximal exercise intensities, compared to untrained individuals[15].

Although previous studies do not present a correlation between aerobic power and shooting performance at rest, immediately after performing a physical effort, individuals with lower aerobic capacity tended to worsen their performance[9,10]. Other studies indicated that aerobic fitness did not correlate with parameters of aiming or shooting efficiency[3]. In a recent systematic review including 23 studies, Simas et al.[16] concluded that physical effort does not decrease shooting performance at distances less than 10m from the target, not even when carrying weights related to their equipment or vests.

Evans et al.[8] verified that although the shooting decreased immediately after the exercise, several variables returned to their initial values after a five-minute recovery, and all the studied parameters were recovered after ten minutes. However, they used a rifle, a long type of firearm, which may have been influenced by causing greater contact with the body in its grip[8]. Sattlecker et al.[17] suggested that the increase in respiratory activity, HR, and muscle fatigue cause oscillation of the armament, and better performance is also linked to shoulder strength. However, none of the previous studies presented a condition of physical exertion that simulated a foot chase inherent to police activity.

Body composition can also influence shooting performance since anthropometric variables linked to the amount of lean mass or obesity are directly related to the activation of the sympathetic autonomic nervous system and increased blood pressure[18]. In this regard, higher abdominal and visceral fat levels may present higher impacts, especially for cardiovascular and autonomic alterations. The waist-to-hip ratio (WHR) is an indicator of body mass distribution, which may indicate the relationship between central (i.e., abdominal) and peripheral (i.e., hips) accumulation of fat, which can be used as a reference due to its ease of use and low cost[19]. Age is also another factor to be considered since aging can increase cardiovascular sympathetic activity by reducing parasympathetic activity, which can be modified or attenuated by regular exercise since improving or maintaining physical fitness can delay the decline in parasympathetic modulation that occurs with normal aging[20]. However, no studies related shooting performance to age or body composition were found.

Thus we aimed to evaluate the correlation between anthropometric, cardiovascular, and aerobic fitness variables with shooting performance at rest and after physical exertion in police officers which is important for police preparation. We hypothesized that variables related to individual characteristics may be differently associated with shooting performance at rest and after physical exertion. Therefore, we aimed to evaluate the correlation between age, aerobic fitness, anthropometric, and cardiovascular hemodynamic variables with shooting performance before and after physical exertion in police officers.

MATERIALS AND METHODS

Study design

This cross-sectional exploratory study comprised two sessions with a 72-hour interval. In the first, participants underwent anamnesis, anthropometric and cardiovascular hemodynamic evaluation, and familiarization with the air pistol, followed by a maximum incremental test. The second session involved a shooting test before and after running on an obstacle course simulating a foot chase. Participants were instructed to abstain from caffeinated and/or alcoholic beverages and avoid exercise 24 hours before assessments. All sessions occurred between 7 and 9 am. The Institutional Ethics Committee approved the study (CAAE: 31266114.3.0000.5537), and participants provided informed consent before data collection.

Sample

A convenience sample of 15 male military police officers with ≥ 6 years of experience participated in the present study. The inclusion criteria were (a) being part of the urban policing of the Military Police; (2) having a body mass index <30kg/m^2; (3) not having any musculoskeletal condition that would prevent physical exertion and not using medication that would alter the studied variables. The exclusion criteria were injuries during the study that interfered with the outcome variables and not complete any part of the experiment.

Anthropometric assessment

Body mass and height were measured with a digital scale and stadiometer (Welmy®, W110H, São Paulo, Brazil). Body mass index (BMI) was calculated as mass divided by height squared. Waist circumference (WC) at the umbilicus and hip circumference (HC) at the largest gluteal proportion were measured with a flexible metallic tape in centimeters. Waist-to-hip ratio (WHR) was calculated as WC divided by HC.

Cardiovascular hemodynamic evaluation

Systolic blood pressure (SBP) and resting heart rate (HR) were assessed with an Omron® digital blood pressure monitor (742 INT, Kyoto, Japan) following five minutes of rest. Three measurements were conducted at one-minute intervals, and the average was utilized for analysis. Before the measurements, participants were advised to visit the bathroom and empty their bladder if needed.

Assessment of aerobic fitness

Aerobic fitness was assessed with a maximal incremental treadmill test (Inbramed ATL, Porto Alegre, RS, Brazil). Following a 5-minute warm-up at 5 km/h without inclination, the test started at 8 km/h, increasing by 1 km/h/min until voluntary exhaustion, with continuous HR monitoring using a cardiac monitor (RS800cx, Polar Electro OU, Kempele, Finland)[21].

Gas exchange analysis employed a breath-by-breath gas analyzer (Cosmed, Quark CPET, Rome, Italy). Calibration, following the manufacturer's recommendations, used standard gases and a 3L syringe. Post-test, 20-second averages were analyzed, and the highest average during the incremental test represented peak oxygen uptake (VO_{2peak}).

Evaluation of shooting performance

The shooting test was performed before and immediately after the physical effort. Five shots were fired at the target positioned 8 meters away and 1.65 m high. The shots were aimed at punctuated shooting targets, with the circle in the center of the target with a 1 cm diameter corresponding to 10 points. The circles increased by one centimeter in diameter from the center to the outside, and the score decreased by one point (Figure 1). To perform the shots, participants had to be in the initial position with the weapon next to the thigh on the dominant side, as if it were in a holster. At the "go" command, the policemen should draw the gun, take aim and shoot. The officers were instructed to shoot as accurately (i.e., achieving the highest score) and as fast as possible. The time elapsed between the verbal command and the execution of each shot was recorded with a digital stopwatch by a single, previously trained evaluator. To perform the shooting test, initially, the volunteers became familiar with the air pistol (Beeman® 2004, caliber 4.5 mm, 0.77 kg) by performing three shots. The score and time for each shot were recorded.

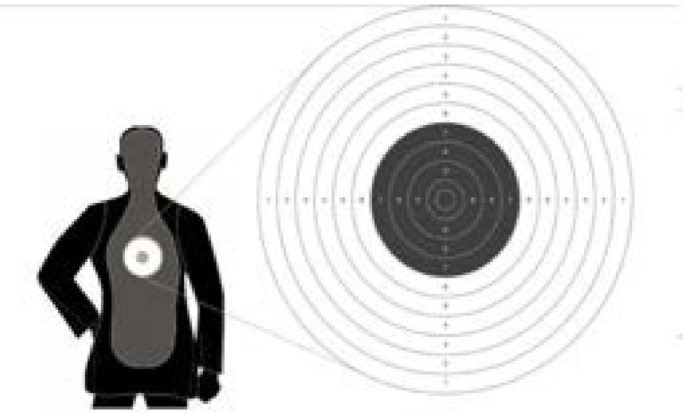

Figure 1. A humanoid figure used for evaluation of shooting performance (left) with the punctuated shooting target, enlarged on the right.

Running task

The physical effort was performed by having participants run on a course with obstacles that aimed to resemble a real chase that police officers could face in the "real world" (Figure 2). The total course of the track comprised a distance of 297 m with five obstacles: 1) going up and down a slope with sandy soil of approximately 30 meters (15 m uphill and 15 m downhill), similar to a dune; 2) after running in a straight line, enter through a narrow door opening in a one-room building and exit over a wall approximately 1.00 m high; 3) perform a sinuous race (zigzag) between three flagpoles positioned one meter apart from each other; 4) perform the kneeling shooting

Table 1. Characterization of the sample of 15 male police officers participating in the study (n = 15).

Variable	Mean (standard deviation)
Age (years)	34.1 (5.4)
Experience time	9.7 (6.9)
Body Mass (Kg)	81.5 (8.8)
Body mass index (kg/m^2)	27.7 (2.3)
Waist-to-hip ratio	0.89 (0.04)
Systolic blood pressure (mm/Hg)	117.2 (12.4)
Diastolic blood pressure (mm/Hg)	75.0 (4.0)
Resting Heart Rate (bpm)	63.9 (7.5)
Aerobic power (ml·kg-1·min-1)	44.9 (4.0)

position (one of the knees on the ground and the other bent forward to provide support) in four locations demarcated by cones two meters apart, in an approximate Z shape; 5) cross the first obstacle of the circuit in the opposite direction again, ending the race at the starting point. Volunteers were instructed to complete the circuit as quickly as possible, and strong verbal encouragement was given throughout the performance. The time to complete the course was registered using a digital stopwatch, and HR was continuously recorded. The police officers wore light clothing and shoes suitable for physical exercise.

Figure 2. Satellite image, obtained through Google Maps, of the place where the physical effort was carried out and edited with the indication of obstacles on the track. Zero (0) indicates the starting and ending point near which the shooting tests were carried out. The arrows indicate the direction of running. The numbers correspond to the type of obstacle: (1) up/down a sandy soil; (2) entering a room and jumping over a 1-meter-high wall; (3) zigzag running using flagpoles; (4) four repetitions of kneeling shooting aiming; (5) up/down a sandy soil.

Statistical analysis

The normality of the data distribution was confirmed by the Shapiro-Wilk test. Data were presented as mean and standard deviation. Pearson's correlation coefficient (r) was used to analyze the correlation between anthropometric variables (WHR), cardiovascular hemodynamic variables (SBP), aerobic fitness (VO_{2peak}), and shooting performance before and after physical exertion. The magnitude of the correlation was interpreted as weak ($0.3<|r|<0.5$), moderate ($0.5<|r|<0.7$), strong ($0.7<|r|<0.9$), and very strong ($|r|>0.9$) correlation[22]. An additional linear regression analysis was included when the variables presented significative correlation. $P < 0.05$ was adopted. SPSS 28.0 software was used for all analyses.

RESULTS

Participants' characteristics are described in Table 1. Moreover, participants completed the running course in 75.3 ± 4.4 seconds with ~85% of the maximum HR achieved in the maximum incremental test. Age and SBP were not correlated (r=0.225; p=0.421).

Shooting performance at rest showed a strong negative correlation with Age (Figure 3A) and a moderate negative correlation with SBP (Figure 3B). Linear regression was significant between the score in the shooting test before physical exertion and age (R^2=0,51; $F_{(1, 13)}$=13.5; p=0.003), SBP (R^2=0,289; $F_{(1, 13)}$=5.27; p=0.039), and experience time (R^2=0,65; $F_{(1, 13)}$=9.55; p=0.009); regression between the score in the shooting test after physical exertion and experience time was significant (R^2=0,7; $F_{(1, 13)}$=12.6; p=0.004).

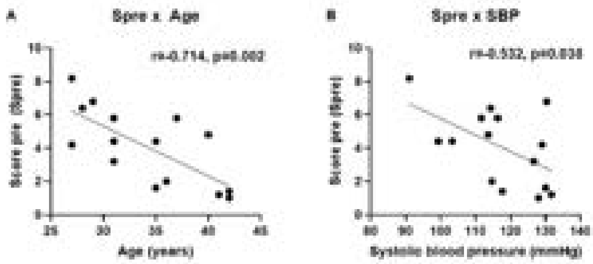

Figure 3. Significant correlations between the variables studied and shooting performance. (A) strong negative correlation between the score in the shooting test before physical exertion (Spre) and Age; (B) moderate negative correlation between Spre and systolic blood pressure (SBP) measured at rest; "r" represents Pearson's correlation coefficient and "p" represents statistical significance.

VO_{2peak} showed a strong negative correlation with the time taken to go through the circuit (r = -0.64; p = 0.01). No other significant correlations were found (Table 2).

DISCUSSION

The study explored correlations between age, aerobic capacity, anthropometric, and cardiovascular hemodynamic variables with police officers' shooting performance at rest and after a simulated foot chase. Our main finding revealed negative correlations between age, SBP, and experience time with shooting performance at rest, and experience time and score after physical exertion. No other variables correlated with shooting performance pre- or post-exertion. Aerobic capacity is negatively correlated with circuit completion time. This supports our hypothesis that individual characteristics, anthropometrics, cardiovascular hemodynamics, and cardiorespiratory fitness may be differently associated with shooting performance at rest, with no observed influence after physical exertion.

The negative correlation between age and shooting performance agrees with the increased sympathetic activity and reduced parasympathetic activity caused by age[20]. However, this change in modulation with aging seems more linked to increased blood pressure than age itself[20]. Moreover, caution should be taken when considering the relationship between age and shooting performance because the shooter's experience time is a relevant variable since, through the practice of the specific shooting activity, they can attenuate the amount of psychological stress[16], improve the accuracy of fine motor movements and reduce possible decreases in accuracy that may occur due to increasing age[23]. Indeed, our data shows that the experience

Table 2. Analysis of the correlation between different anthropometric and hemodynamic variables, aerobic fitness, and shooting performance before and after exertion in police officers (n = 15).

Variables	Shooting performance			
	At rest		After physical exertion	
	Score	Shooting time	Score	Shooting time
Age	**r=-0.714***	r=-0.216	r=-0.455	r=-0.330
Experience time	**r=-0.651***	r=0.349	**r=-0.702***	r=0.321
Waist-to-hip ratio	r=-0.328	r=-0.102	r=0.295	r=0.151
Systolic blood pressure	**r=-0.532***	r=-0.437	r=-0.102	r=-0.051
Resting Heart Rate	r=-0.321	r=0.121	r=-0.163	r=-0.046
Peak oxygen uptake	r=0.044	r=-0.285	r=-0.464	r=-0.257
Running completion time			r=0.276	r=0.373
Maximum heart rate in the circuit			r=0.409	r=-0.034

Note: * *$p<0.05$;*
r= correlation coeficiente.

time seems to explain the results better than age itself, independently of physical exertion.

WHR is an indirect measure used to estimate the distribution and accumulation of body fat in the central part of the body. Adipose cells produce a variety of adipokines and cytokines that can influence the local vascular tonus[24] that, when unbalanced, can be inflammatory agents and cause vasoconstriction[25]. Although a greater portion of fat is suggested to be correlated with increased cardiac sympathetic modulation[26], in the present study, there was no relationship between WHR and shooting performance either at rest or after exercise. In addition, the absent correlation can be explained by the good level of fitness and experience of the participants since, in addition to fat mass, lean mass can also influence blood pressure levels[24]. Goossens[27] points out that different body fat distributions in the body have different effects on metabolism. More accurate body fat measurements such as dual x-ray absorptiometry or magnetic resonance would be better to analyze the possible relationship between body fat and shooting performance, since the WHR, despite its low cost and ease of use, does not consider the whole-body composition.

SBP was the only hemodynamic variable significantly correlated with shooting performance at rest. The negative correlation indicated that a higher SBP was associated with a lower shoot score. According to Lakie[6] force impulses generated by the pulsatile momentum of each heartbeat produced by the transitory oscillation of the blood through the limb cause a physiological tremor. Thus, a greater SBP would cause greater limb oscillation, impairing shooting performance[6]. It has also been suggested that an increase in HR, or a delay in returning to resting levels after physical exertion, increases tremor, which would lead to impaired shooting, which was not found in this study. The resting HR did not correlate with any shooting performance variable, which can be explained by the low values presented by the sample (64 ± 7.45 bpm). It should be noted that HR and SBP were measured at rest the day before the running test, which may explain why blood pressure was associated with shooting performance before the effort, but not after it.

Significant physiological adjustments are required to control the stress response during the time elapsed between the end of the running task and the post-physical effort shooting. Thompson et al.[2] verified that heart rate recovery (i.e., the difference between HR at the end of the physical effort and HR at the moment of the first shot; HRR) is significantly related to shooting performance and is even associated with cognitive control. Ortega et al.[28] also verified that HRR predicts shooting performance since the heartbeat intervals are longer by lowering the heart rate, and shooters have a larger window to shoot. They also suggested that at the beginner level, this longer interval may impact effectiveness, but over time the shooters adjust the speed of their shot, performing it more efficiently before ventricular systole. As the participants in the present study had at least six years of experience, this may have been a factor that justified the non-correlation of shooting performance with HR, even after exercise.

Shooting performance after physical exertion was not correlated to SBP, resting HR, and maximum HR achieved during the running task. Although it was observed that the participants reached a high $\%HR_{max}$ during physical exertion, this did not influence their performance when shooting immediately afterward. Similarly, Brown et al.[3] also did not find in HR a predictor of shooting performance before or after physical exertion. HRR can also provide relevant information about the control of the autonomic nervous system[29]. In this regard, shooters who recover faster (i.e., a greater decrease in HR after exercise) would present better shooting performance. Unfortunately, HRR was not evaluated in this study, and future studies should consider this variable in their assessment.

Cardiorespiratory fitness (VO_{2peak}) objectively measured was not correlated with shooting performance at rest or after the physical effort. At rest, a higher VO_{2peak} could be associated with greater parasympathetic cardiac autonomic control and could have reduced heart-related tremors after exertion[30]. Moreover, higher VO_{2peak} results in a lower physiological disturbance during the physical effort[31], resulting in easier shooting stabilization afterward. However, this association was not confirmed. On the other hand, we verified a strong negative correlation between VO_{2peak} and the time to complete the running task, indicating that more fit police officers ran faster than their less-fit peers. Dias et al.[9] showed that physical exertion would cause a reduction in shooting efficiency and suggested physiological alterations as the main reasons for that. The differences in results could be attributed to the type of gun used because while the current study used an air pistol, Dias et al.[9] used an air rifle, which has more contact points with the body due to its size/length, making it more susceptible to the influence of body sway and tremor. This may indicate that the influence of physiological stress caused by physical effort on shooting performance depends on the type of weapon used.

Limitations and future directions

A potential study limitation is that police officers performed the running task in light clothing and running shoes, excluding the impact of carrying their usual equipment. In real-world scenarios, carrying a gun, bulletproof vests, and other gear may affect physical performance, induce muscle fatigue, and alter physiological distress levels. Additionally, the use of a compressed air pistol, due to its size, weight, and lack of recoil, may have influenced the absence of correlations between study variables and shooting performance. Unlike long-barreled weapons, pistols require stable upper limb positioning, and the absence of recoil minimizes body/aiming adjustments.

Future studies should consider participants' experience duration in the specific activity and how the HRR may correlate with tremor reduction and improved post-exertion shooting results. Factors such as using realistic recoil-producing weapons during running tasks might influence the results. Also, other physiological variables should be included, such as heart rate variability, since the autonomic system might be important to shooting performance. Also, this study's sample size is very small, limiting the generalization of the results. Lastly, firearm decision-making involves complex task control and requires good executive function performance, including attention, emotional control, and the ability to ignore irrelevant. Research is needed to explore not only physical characteristics and correlations but also cognitive abilities.

CONCLUSION

The results of the present study suggest that age and SBP may be negatively related to resting shooting performance in police officers. It was also found that the other variables studied did not correlate with shooting performance. However, the physical fitness of the sample may have been a factor to be considered for not observing these correlations. In this way, good physical conditioning may have influenced shooting performance, which impacts police preparation, given the importance of acting on all factors that minimize damage when using firearms and increase their effective use.

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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