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REVISTA DE CIENCIA Y TECNOLOGÍA EN LA CULTURA FÍSICA

Translated from the original in spanish

Original article

Air pistol shot efficacy under normal and excited conditions

Eficacia en el tiro de la pistola de aire bajo condiciones normales y de excitación

Eficiência de tiro com pistola de ar em condições normais e de excitação

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ABSTRACT

Shooting is practiced mostly by police or military, it has become an Olympic sport where the air pistol test stands out, which requires extreme mental concentration and precision in its movements to achieve effectiveness in the shot. In this work, the authors aim to identify the kinematic data of the arm-weapon complex in normal and excited state during the execution of the shot, considering variables such as heart rate, the effectiveness of the shot and the angles of the main joints (glecohumeral) that allow the execution of the technique. As part of the methodology, this research was implemented in the closed shooting range of the Escuela Superior Militar "Eloy Alfaro" and seven

athletes that form the shooting teams of the Ecuadorian Army and Air Force were analyzed. The heart rate (in four phases), the effectiveness of the shot (in three opportunities) and the angle of the glenohumeral joint in resting and excited states were analyzed, where the pertinent comparisons were made. As results of the study, it is shown that the mean values of the heart rate were significantly different (p=0.001), being higher in the excited state. The effectiveness of the shot does not establish significant differences (p=0.620) between states, as well as the glenohumeral joint angles (p=0.209). It is concluded that there are no significant differences in the effectiveness of shooting in excitement and at rest, an indicator of good physical preparation, although there is less effectiveness of shooting in the excited state.

Keywords: Olympic shooting; Heart rate; Shooting effectiveness; Joint angles.

RESUMEN

El tiro es practicado en su mayoría por policías o militares. Ha llegado a ser un deporte olímpico donde se destaca la prueba de pistola con aire, la cual requiere una concentración mental extrema y precisión en sus movimientos para lograr efectividad en el disparo. En este trabajo, los autores se propusieron como objetivo identificar los datos cinemáticos del complejo brazo-arma en estado normal y de excitación durante la ejecución del tiro, considerando variables a la frecuencia cardíaca, la efectividad del disparo y los ángulos de las principales articulaciones (glecohumeral) que permiten la ejecución de la técnica. Como parte de la metodología, esta investigación se implementó en el polígono de tiro cerrado de la Escuela Superior Militar "*Eloy Alfaro*" y se analizaron a siete deportistas que conforman los equipos de *Tiro de la Fuerza Terrestre y Aérea ecuatoriana*. Se analizó la frecuencia cardíaca (en cuatro fases), la efectividad del disparo (en tres oportunidades) y el ángulo de la articulación glenohumeral en estado de reposo y en excitación, donde se realizaron las comparaciones pertinentes. Como resultados del estudio, se muestra que los valores medios de la frecuencia cardíaca fueron significativamente diferentes (p=0.001), al ser mayores en estado de excitación. La efectividad del disparo no establece diferencias significativas (p=0.620) entre estados, al igual que los ángulos de la articulación glenohumeral (p=0.209). Se concluye que no hay diferencias significativas en la efectividad de los disparos en excitación y en reposo, indicador de una buena preparación física, aunque hay menor efectividad del disparo en estado de excitación.

Palabras clave: Tiro olímpico; frecuencia cardíaca; Efectividad del disparo; Ángulos articulares.

RESUMO

O tiro é praticado principalmente pela polícia ou militares, tornou-se um desporto olímpico onde se destaca o exame da pistola de ar, o que requer uma concentração mental extrema e precisão nos seus movimentos para se conseguir eficácia no tiro. Neste trabalho, os autores visam identificar os dados cinemáticos do complexo braço-arma em estado normal e excitado durante a execução do tiro, considerando variáveis como o ritmo cardíaco, a eficácia do tiro e os ângulos das articulações principais (glecohumeral) que permitem a execução da técnica. Como parte da metodologia, esta pesquisa foi implementada na carreira de tiro fechado da Escola Superior Militar "Eloy Alfaro" e foram analisados sete atletas que compõem as equipas de tiro do Exército e da Força Aérea equatoriana. O ritmo cardíaco foi analisado (em quatro fases), a eficácia do tiro (em três oportunidades) e o ângulo da articulação glenoumeral em estado de repouso e em

excitação, onde foram feitas as comparações correspondentes. Como resultados do estudo, mostra-se que os valores médios da frequência cardíaca eram significativamente diferentes (p=0,001), sendo mais elevados no estado excitado. A eficácia do tiro não estabelece diferenças significativas (p=0,620) entre estados físicos, bem como os ângulos de articulação glenoumeral (p=0,209). Conclui-se que não há diferenças significativas na eficácia de disparar em estado de excitação e em repouso, um indicador de boa preparação física, embora haja menos eficácia de disparar em estado de excitação.

Palavras-chave: Tiro olímpico; Frequência cardíaca; Eficácia do tiro; Ângulos articulares.

INTRODUCTION

Currently, shooting is practiced in police or military activities, for enjoyment and competitively (Peña, 2007). In the latter, there are several modalities, among which Olympic shooting stands out, specifically the air pistol shooting test. This sport, due to its characteristics, requires extreme mental concentration and the precision of its movements in order to have a successful shot (Pellegrini & Schenna, 2005).

The fundamental position for this modality is standing, where the shooter must aim at a target consisting of concentric rings with a determined score; starting from ten with the inner ring and decreasing by one unit with each ring towards the outside. The outer ring score has a diameter of 16.5 cm, while the tenth ring has a diameter of only 1.15 cm. In air pistol at ten meters, a gun movement of 0.0016° is sufficient to score a minor score (Pellegrini & Schenna, 2005).

In the methodology of the shooter's specific training in favor of obtaining a higher performance, the athlete must perfect his postural control (González López, et al., 2019). In this modality, their muscles must be kept fit for isometric regimes and the entire weight of the pistol must be supported throughout the competition, (Lourenço & Silva, 2013). Hence, the design of the content of the Olympic shooter's preparation prioritizes the components of the preparation (Ibarra, Jáuregui, Matienzo, & Cárdenas, 2018).

For the specific case of Ecuador, Olympic shooting athletes do not systematically meet the marks that allow them to reach international levels, which cause a deficit of sports results. This makes it necessary to take corrective actions and, above all, to generate information specific to the context of national shooters, given the lack of studies that allow coaches to propose pertinent strategies, in order to improve their training process.

Under these conditions, it is undoubtedly that the small movements of the body and of the arm complex with the weapon are of utmost importance during the aiming at the target phase, for which there diverse literature such as the one is presented by Ibarra, Jáuregui, Matienzo, & Cárdenas (2018). This proposal establishes specialized training strategies to enhance preparation components such as technique, as it plays an important role in the shooter's performance. In this way, it is of vital interest to collect better information on the movement patterns of the arm-weapon complex, (Pellegrini & Schenna, 2005) among other aspects to determine individual potentialities that may affect the effectiveness of the shot.

On the other hand, it has been identified that the marks of athletes in training differ significantly from those obtained during competition. This difference is produced, among others, by the increase in heart rate, generated by multiple factors such as anxiety and the pre-start state of the shooters, the altitude of the competition site, sport technique, vision and the enhancement of physical capacities, among other factors (González-Carballido *et al.,* 2013).

For the specific case of the potentiation of physical capacities determinant for the effectiveness of Olympic shooting, the literature consulted evidences the importance of endurance to maintain the effectiveness of the shot, Hernández, Aroca, Herreño, & Gutiérrez, (2019). The documentary review evidences that the application of aerobic exercises allows decreasing tension, which increases the systolic ejection volume. These exercises allow the development of more controlled shots and corroborate that the study of the performance and influence of physical endurance can be a significant factor to achieve effectiveness in the process of sports training applied to shooting, in any modality.

Therefore, the purpose of the research is to identify kinematic data of the arm-weapon complex in normal state and under excitation conditions during the execution of shooting in elite athletes. These athletes belong to the teams of the Ecuadorian Air Force and the Ecuadorian Air Force and experience the effectiveness of shooting by considering the variables of heart rate, the effectiveness of the shooter and the angles of the main joints that allow the execution of the technique in upper limbs.

MATERIALS AND METHODS

For the development of this study, seven air pistol shooting athletes were analyzed (3: female and 4: male), who formed the shooting teams of the Ecuadorian Air Force and the Ecuadorian Air Force. The research was conducted in the closed shooting range of the Escuela Superior Militar "Eloy Alfaro", complying with the standards imposed by the ISSF (International Shooting Sport Federation). For the study, targets were used at a distance of 10 meters.

On the other hand, the FEINWERKBAU P44 pistol was used as armament, which has a caliber of 4.5 mm. (.177). This single-shot air pistol has been created for high competition, which has elimination of recoil by means of a patented absorbing block. The gun is made of tungsten alloy; it has an adjustable sight distance from 360 to 395 mm. and has adjustable grips in three sizes, with the possibility of rotating them by 3º and tilting them by 10º. In addition, this implement has an adjustable pressure point and a trigger shoe type trigger, adjustable in position in all directions. The weight of the firing pin was 4.2 g.; for this, a compressed air cylinder with integrated pressure gauge is available.

To monitor the athletes' heart rate, a Garmin Vivo Active 3 heart rate monitor with HRM-RUN chest band sensor was used. To monitor shooting efficiency and analyze the shooter's coordination, the SCATT system was used, which is composed of an MX-02S sensor. This system transmits all the aiming and shooting efficiency information through a USB cable to a computer where a SOFTWARE is installed. This computer resource allows to show in real time the trajectory of the muzzle of the weapon and records the phases of the execution of the shot. Finally, the entire execution of the shot was recorded

with a SONY Handy Cam HDR-PJ380 8.9 megapixel digital camcorder. This camera was mounted on a professional tripod 2.5 meters away from the athlete, focusing on two axes for the subsequent biomechanical analysis with the KINOVEA system.

The evaluation was carried out in one day, having as a protocol that each athlete had to serialize his weapon in such a way that the effectiveness and functioning of the SCATT system was evidenced. Subsequently, they were induced to a state of rest for 60 seconds, while they remained seated next to the shooting area. Once this time was over, the first phase, which corresponded to the normal or resting state, was initiated. This consisted of performing 3 shots with a time limitation of 15 seconds for each shot and 5 seconds of transition from shot to shot.

For the second phase of the evaluation, which consisted of executing the shot in a state of arousal, an activity with dual functionality was introduced. This utility consisted of creating an increase in heart rate and generating a cognitive response through the displacement of the athlete in an equilateral triangle of 3 m. in length. This equilateral triangle formed by cones leads the athlete to relocate to the center and move as fast as possible towards the indicated cone. From here, a response is obtained by an acoustic signal (loudly) for 30 seconds, to then run towards the zone and execute the shot within 15 seconds. In the study, 3 repetitions are considered for the effect and a macropause of 60 seconds of recovery is maintained between each shot.

All the information collected was recorded in the SCATT system and was analyzed by means of central tendency and correlation statistics, using the Mann-Whitney U test. Being independent samples ($p \leq 0.05$), significant differences are determined and the hypothesis of the research work is corroborated.

For the biomechanical analysis, the Kinovea Software was used and the angles referred by the main joint used in the execution of pistol shooting are used as magnitudes. Finally, the existence of significant differences between men and women is verified.

RESULTS AND DISCUSSION

As can be seen in the following tables, the individual shot execution of the athletes in the resting state (Table 1) and in the excited state (Table 2) is evidenced. From here, the average initial heart rate, the average heart rate in the execution of each of the shots and the average of the scores obtained during the activity are obtained.

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Table 1. - Results obtained in the shot in resting or normal state

ATHLETE	In rest									
	HEART RATES					SHOOTING EFFECTIVENESS				ANGLES
	FC Initial	FC EN T1	FC EN T2	FC EN T3	FC $\bar{X}$	T1	T2	T3	T $\bar{X}$	(°)
SUBJECT 1	70	82	76	90	83	8,5	10,3	10,2	9,7	94,7
SUBJECT 2	73	84	94	92	90	9,3	9,3	6,1	8,2	95,2
SUBJECT 3	73	83	93	82	86	8,6	8,8	8,5	8,6	93,7
SUBJECT 4	67	83	84	79	82	8,5	7,7	7,2	7,8	92,5
SUBJECT 5	60	60	69	64	64	4,1	9,5	5,5	6,4	90,8
SUBJECT 6	81	83	90	81	85	8,3	9,0	10,3	9,2	91,2
SUBJECT 7	58	70	73	69	71	8,8	8,5	8,3	8,5	92,7
$\bar{X}$	**69**	**78**	**83**	**80**	**80**	**8,01**	**9,01**	**8,01**	**8,35**	**92,97**

Table 1 shows the means or averages obtained in each indicator of analysis, where the mean of the initial heart rate (HR) was established at *X*69 p/m. The FC in the first half was *X*78 p/m; in the second half, *X*83 p/m and in the third half, *X*80 p/m. In the execution, there is a general average of the HR at *X* 80 p/m. On the other hand, the efficiency of the shot was established in its first evaluation at 8.01 points; in the second evaluation, at 9.01 points; in the third evaluation, at 8.01 points, with a mean score of 8.35 points. In parallel to this, the angle studied obtained an average of 92.97°.

Table 2. - Results obtained in the shooting in the excited state

ATHLETES	In excitement									
	HEART RATES					SHOOTING EFFECTIVENESS				ANGLES
	FC INITIAL	FC EN T1	FC EN T2	FC EN T3	FC $\bar{X}$	T1	T2	T3	T $\bar{X}$	(°)
SUBJECT 1	76	162	170	168	167	8,0	6,8	9,7	8,2	95,2
SUBJECT 2	83	132	153	148	144	10,1	9,2	9,2	9,5	96,1
SUBJECT 3	74	135	145	140	140	9,5	6,1	9,8	8,5	94,7
SUBJECT 4	76	145	157	153	152	7,0	4,8	7,3	6,4	93,8
SUBJECT 5	73	128	139	137	135	0,0	9,4	5,1	4,8	91,3
SUBJECT 6	88	150	163	155	156	8,3	7,8	9,0	8,4	93,7
SUBJECT 7	79	157	163	158	159	9,1	9,3	8,4	8,9	93,7
$\bar{X}$	**78**	**144**	**156**	**151**	**150**	**7,40**	**7,60**	**8,40**	**7,80**	**94,071**

Table 2 shows the means obtained in the indicators analyzed, where the mean initial heart rate (HR) was established at *X*78 p/m; the HR in the first half at *X*144 p/m; in the second half at *X*156 p/m and in the third half at *X*150 p/m. An overall mean HR of 150 bpm prevailed in the study. On the other hand, the shooting efficiency was established in its first evaluation at 7.40 points; in the second evaluation, at 7.60 points; in the third evaluation, at 8.40 points, with a mean score of *X*7.80 points. As a result, an average of 94.071° is established for the studied angle.

For the present table analyzed, it is evident that all the evaluations performed in the excited state were lower than those performed in the resting state, with the exception of the third shot (*X*8.40 points).

A more detailed comparison between the values obtained in both tests is evidenced by applying the Mann-Whitney U test. Here it is shown that the mean values of Heart Rate (HR*X*)) were significantly different (p=0.001) in favor of the resting state test (4.00). These values behave this way, given a lower mean range compared to the tests in excited state (11.00). These tests indicate an affectation of the organic homeostasis,

after a physical-cognitive activity of 30 seconds duration. This affectation could have implications on the effectiveness of firing. Thus, the importance of aerobic development for the improvement of VO2 max, which contributes to improve heart rate recovery as stated by Molander and Backman (1989), is demonstrated. Thus, it is confirmed that the kinetics of heart rate recovery is higher in individuals who regularly perform aerobic exercise, as well as pre-competition frequency and peripheral vascular resistance.

On the other hand, when comparing firing efficiency, the data do not establish significant differences (p=0.620), which indicates a relatively similar effectiveness between both tests. However, this effectiveness is shown to be slightly lower in the arousal state (6.93), given the existence of a lower average range than that determined in the resting state (8.07). Therefore, a moderate intensity resistance training such as the 30 s. stimulus applied immediately before shooting can create technical imbalances that imply a decrease in effectiveness. This implies that the greater the body arousal, the lower the effectiveness of the shot. However, given the size of the sample investigated and the characteristics of the physical stimulus, further studies related to the present field of action are recommended.

In such sense, the exposed by Nascimiento Neto *et al.,* (2017) where they mention, from his study, that the physical effort made prior to a shooting performance does not necessarily affect the shooting performance in his study (military police officers). On the other hand, the level of aerobic adaptation does not correlate with the performance of the shooters, but it is important for the effective performance of the shooting to carry out a previous physical preparation that is as optimal as possible.

In the case of the angles studied, there is also no significant difference (p=0.209). This presents a greater angle of the gleno-humeral joint in the excited state (9.00) than in the resting state (6.00). Therefore, the athlete tends to make a greater effort at the moment of gripping and aiming the weapon at the target, as visually evidenced in the example (Figure 1).

Fig. 1- Angles of the glenohumeral joint in the throw. Resting and Excitation States

In parallel, as there is a correlation between the angle of the studied joint and the center of gravity of the athlete, this center changes according to the proximity of the arm to the midline of the body, this is confirmed by Pellegri and Schenna (2005). Here it is explained that slow deviations and shooting technique mainly affect the lateral movements of all body segments, creating a probable sway in the athlete's posture. In the same sense, vertical displacements may refer to the movement of the gleno-humeral and radius carpal joint with typical characteristics of physiological tremor.

CONCLUSSIONS

In general, it is concluded that, when analyzing the aforementioned data, it is evident that there are no significant differences in the effectiveness of the shots in arousal and at rest. This is a result that indicates an adequate physical preparation in the studied athletes, at least from the point of view of physical endurance. In spite of the absence of significant differences in the effectiveness of the shot, the analysis of the average ranges shows that the effectiveness is lower in the excited state than at rest.

From this, it can be deduced that the greater the physical excitation, the lower the accuracy of the shot; further study of this aspect is recommended. The angles of the gleno-humeral and radius carpal joints vary in the state of rest and excitation and generate a decrease in efficiency in the latter state. This phenomenon is caused by the change in the center of gravity of the athlete and the increase in horizontal and vertical displacements typical of physiological tremor. As a result, this inefficiency is caused by increased heart rate, as evidenced by Peter, Ľubomíra, Denis, & Matúš, (2020).

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Conflict of interests:
The authors declare not to have any interest conflicts.

Authors' contribution:

Pablo Cruz Perugachi: Conception of the idea, literature search and review, compilation of information resulting from the instruments applied, general advice on the topic addressed, drafting of the original (first version), article correction, authorship coordinator.

Jefferson Rueda Rosales: Conception of the idea, instrument making, instrument application, compilation of information resulting from the instruments applied, statistic análisis, preparation of tables, graphs, and images, database preparation, general advice on the topic addressed, review and final version of the article, article correction, translation of terms or information obtained, review of the application of the applied bibliographic standard.