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ORIGINAL SCIENTIFIC PAPER

Evaluation of the Dynamics of the Pressure Applied to the Trigger When Shooting In Biathlon

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Abstract

The presented study is associated with assessing the dynamics of the pressure applied to the trigger when making a shot in biathlon competition. The experiment involved five qualified athletes. The educational work and training sessions were completed with them to improve the trigger handling technique before the experiment. The pressure was recorded using a thin-film elastic sensor located in the contact zone of the biathlete's finger with the rifle trigger. The test task included shooting series from a standing and lying position both before and after loading. Three different trigger manipulation types were identified. The data indicate the feasibility of developing modern systems designed to improve the athlete's shooting profile in terms of the efforts applied to the trigger.

Keywords: *biomechanical analysis, trigger manipulation type, shot phase composition, direct feedback*

Introduction

The speed of overcoming the competitive distance and high-quality shooting at the firing line are the key factors that ensure successful competitiom in biathlon. Moreover, according to current trends, in which the difference in the speed of movement over the distance between athletes is steadily decreasing, the second component has a significant impact on the final result.

The shooting accuracy of biathletes increased, on average, by 3% from 2004 to 2016 (Romanova, Zagurskij, & Gushcha, 2016), and the time spent on firing lines decreased, on average, by 8.8%. Simultaneously, the number of athletes whose accuracy is in the range of 81–85%, on average, increased by 3.9% (males) and (1.7%) females (Romanova et al., 2016; Bolotin & Bakayev, 2017). In this context, it can be argued that the improvement of results in biathlon depends on the degree of reduction in the time spent on firing lines, which can be ensured by increasing the rate of fire. At the same time, it is extremely important to maintain the highest possible level of accuracy (Bakayev, 2015; Romanova & Astaf'ev, 2014; Luchsinger, Kocbach, Ettema, & Sandbakk, 2018; Astaf'ev, 1994; Laaksonen, Finkenzeller, Holmberg, & Sattlecker, 2018; Zagurskij & Romanova, 2017).

A high level of the rate of fire and accuracy is the result of focused work, including all technical elements: preparation, breath-holding, aiming, trigger-handling, rhythm, and intensity. When shooting, these factors have a significant impact on each other. So, the preparation and strategy of holding one's breath determine the features of aiming, which, in turn, together with the trigger processing, determine the rhythm and intensity of shooting. Many trainers note that it is necessary to coordinate the aiming of the weapon and handling the trigger not in the pulse mode of the finger but smoothly since this allows one to reduce the fluctuations of the weapon to a minimum and significantly facilitate aiming (Bakayev, Bolotin, & You, 2018).

In this case, the word "smoothly" is proposed to mean the following: the maximum effort with which the athlete pulls the trigger for one or half a second before the shot should be at least 70% of the maximum possible required for its failure. It

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is argued that compliance with this condition, as a rule, allows one to increase the effectiveness of shooting (Sattlecker, Buchecker, Gressenbauer, & Müller, 2017; Ihalainen, Laaksonen, Kuitunen, & Leppävuori, 2018).

The present research was carried out in close cooperation with biathlon coaches. Its purpose is to evaluate the dynamics of pressure applied by athletes to the trigger after a series of training sessions, during which focused work was carried out to improve the handling of the descent.

Methods

At the coaches' request, the following conditions had to be met when shooting: individual rifles and cartridges; the distance to targets on the firing line was 50 m. To assess the individual dynamics of applied pressure, the "Grip" system (Tekscan, Inc., USA) was used. It enables measuring the contact pressure using a thin-film elastic sensor located in the area of contact of the phalanx of the index finger of the athlete with the trigger of the rifle. The touch element was attached using double-sided tape. Its connector was connected to the data receiver, located on the athlete's forearm using a Velcro cuff. The data recorded during the study was transmitted wirelessly to a computer. The study involved five athletes with experience in biathlon competitions (age 15.8±1.4).

Athletes performed four shooting series of five shots in a multi-purpose universal indoor shooting range from standing and lying positions. The subjects performed simulation exercises on the "SkyErg" simulator before the third and fourth series. The goal is to simulate shooting against the background of an increased heart rate in order to ensure compliance with natural (competitive) conditions better.

MS Excel was used for statistical processing and data visualization. The information obtained that characterizes the individual dynamics of the pressure applied by athletes to the trigger is presented in tabular and graphical form. The pressure values are averaged under conditions of firing before loading, as well as after loading.

The average pressure (P) is normalized to 0–100%, where 100% is the trigger pull. The time moments "T_1", "$T_{0,5}$", "$T_{0,2}$", "$T_{0,02}$" (Tables 1, 2) correspond to 1; 0,5; 0.2 and 0.02 seconds before the shot, and "TP" characterizes the maximum pressure after the trigger is released.

The average pressure profiles are presented in the form of graphs, each with dotted lines indicating the range of its changes, and the following phases are highlighted: phase I, initial pressure build-up; phase II – intermediate; phase III-trigger booster.

Results

The individual dynamics of the pressure applied to the trigger data when firing before and after the load from the lying and standing positions are presented in Tables 1 and 2.

Table 1. Values of the Pressure Applied to the Trigger when Firing from a Prone Position

Athlete number	Time point	Before loading		After loading	
		P±σ,%	t±σ, sec	P±σ,%	t±σ, sec
4	T_1	60.12±12.15	0.94±0.24	52.79±8.76	0.89±0.22
	$T_{0,5}$	67.05±15.51	2.73±0.99	56.59±7.70	1.98±0.48
	$T_{0,2}$	69.43±16.63	3.23±0.99	58.38±7.96	2.48±0.48
	$T_{0,02}$	71.56±17.10	3.58±0.98	60.00±8.48	2.84±0.48
	T_n	118.72±12.35	3.73±0.99	105.61±5.09	2.98±0.48
2	T_1	51.06±11.42	1.63±1.21	56.04±22.29	2.15±1.44
	$T_{0,5}$	69.45±12.09	3.58±1.03	61.77±18.11	3.47±1.51
	$T_{0,2}$	75.75±7.82	4.08±1.03	72.01±14.77	3.97±1.51
	$T_{0,02}$	86.68±9.12	4.45±1.03	85.71±10.37	4.35±1.51
	T_n	108.36±6.47	4.58±1.03	103.49±6.53	4.47±1.51
5	T_1	78.65±19.49	2.01±2.10	58.47±23.12	2.15±1.44
	$T_{0,5}$	101.29±22.33	3.89±1.66	64.47±18.72	3.47±1.51
	$T_{0,2}$	111.45±17.54	4.39±1.66	75.19±15.38	3.97±1.51
	$T_{0,02}$	125.34±22.53	4.76±1.67	89.49±10.8	4.35±1.50
	T_n	153.85±28.07	4.89±1.66	139.54±32.92	4.47±1.51
3	T_1	45.53±9.86	1.28±0.63	56.25±14.62	1.99±0.77
	$T_{0,5}$	67.69±9.71	2.77±1.01	67.18±16.99	2.83±0.85
	$T_{0,2}$	76.31±9.09	3.27±1.01	79.29±11.69	3.33±0.85
	$T_{0,02}$	90.60±9.47	3.58±1.01	86.51±9.96	3.60±0.85
	T_n	111.49±7.10	3.77±1.01	106.21±6.32	3.83±0.85

Information concerning Athlete 1 has been excluded from Table 1, because there are artefacts on the initial recordings that significantly distort them and cannot be filtered. Also, there is no information in Table 2 concerning Athletes 2, 3, and 5 due to their low level of shooting preparedness, as they had recently switched from cross-country skiing to biathlon. Therefore, at this stage, their training is focused on shooting from a prone position.

Table 2. Values of the Pressure Applied to the Trigger when Firing from a Standing Position

Athlete number	Time point	Before loading		After loading	
		P±σ,%	t±σ, sec	P±σ,%	t±σ, sec
1	T_1	43.76±10.12	1.23±0.57	38.66±11.58	0.89±0.54
	$T_{0,5}$	71.07±11.48	2.83±1.22	61.91±12.66	1.79±1.09
	$T_{0,2}$	78.67±8.68	3.33±1.22	73.79±8.49	2.29±1.09
	$T_{0,02}$	87.55±9.21	3.67±1.21	85.52±9.63	2.65±1.08
	$T_{\text{п}}$	110.38±8.68	3.83±1.22	104.03±7.29	2.79±1.09
4	T_1	81.45±12.71	1.64±1.09	71.97±9.12	1.31±1.11
	$T_{0,5}$	86.61±11.79	2.37±1.34	78.21±7.02	2.11±1.68
	$T_{0,2}$	89.76±7.73	2.87±1.34	82.98±4.92	2.61±1.68
	$T_{0,02}$	90.72±6.37	3.25±1.32	85.12±5.91	2.98±1.66
	$T_{\text{п}}$	111.01±8.86	3.37±1.34	105.27±4.54	3.11±1.68

With Athletes 1, 2, and 3, when shooting both before and after loading, when processing the trigger in Phase II, a smoothness change in pressure is observed (Figures 1–3). Biathletes demonstrate a shooting style in which the pressure from the moment the trigger is touched to the moment the shot is fired in Phase III increases linearly, without sharp jumps.

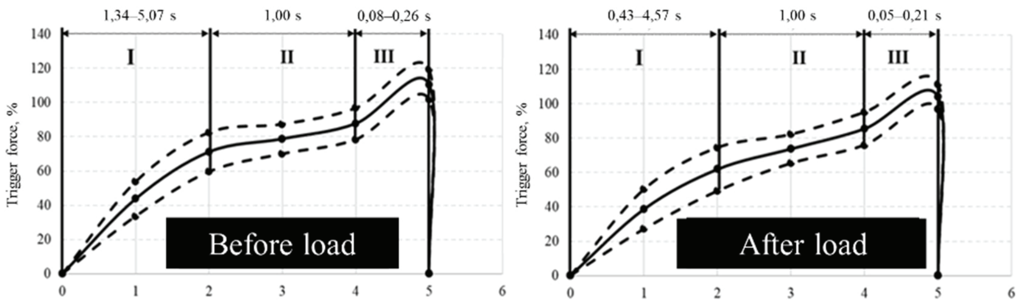

FIGURE 1. Athlete 1's trigger pressure when shooting from a standing position

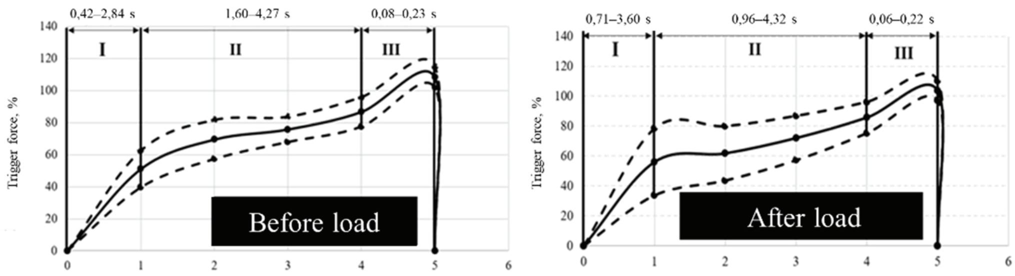

FIGURE 2. Athlete 2's trigger pressure when shooting from a prone position

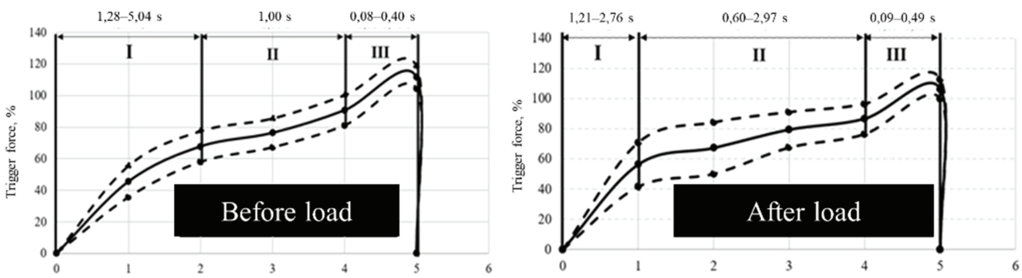

FIGURE 3. Athlete 3's trigger pressure when shooting from a prone position

Athlete 4 has a steady level of pressure when handling the trigger in Phase II (Figure 4). In Phase III, the pressure on the trigger increases evenly. It is noteworthy that when shooting from a standing position, the athlete presses the trigger in Phase III against the background of a high preliminary pressure level. the value of which is, on average, at the level of 90.72% before and 85.12% after loading.

Athlete 5 processes the trigger in pulse mode: only one phase is allocated, during which the pressure increases in a very short period (from 0.04 to 0.26s) to 100% or more (Figure 5).

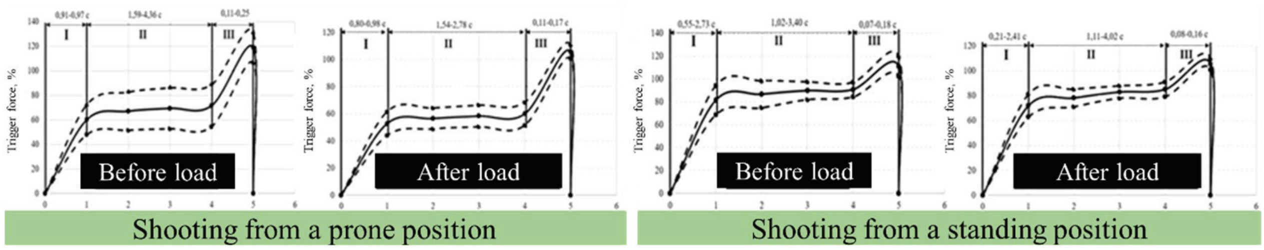

FIGURE 4. Pressure on the trigger by Athlete 4 when shooting before/after the load from the lying and standing positions

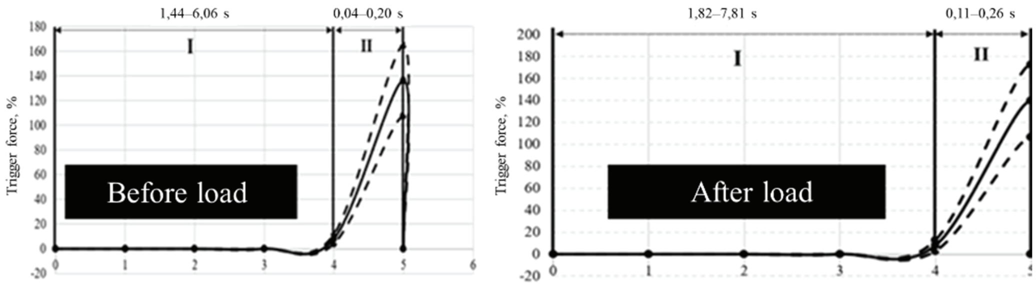

FIGURE 5. Athlete 5's trigger pressure when shooting from a prone position

The results of the study can be used to outline certain conclusions. The motor profile that all athletes demonstrated when handling the trigger can be defined as stable, as evidenced by the corresponding values of standard deviations of pressure. There are three classic types of processing:

- according to the first, the pressure on the trigger increases continuously and linearly. Sharp jumps are not observed throughout its processing, from the first touch of the trigger to the moment of firing (Phases I and III are clearly distinguished, Phase II can be determined by the change in the pressure build-up rate, which is expected to be less than in Phase I);
- the second type can be most fully characterized by the presence of a time interval in it, during which the pressure applied to the trigger can be designated as established, i.e., the athlete reaches a certain value and maintains it;
- in the third type, only one phase out of three can be determined, during which the pressure on the trigger increases abruptly to 100% or more in a very short period (0.3s or less).

There is no direct relationship between the quality of triggering and shooting success (Sattlecker, Buchecker, Rampl, Müller, & Lindinger, 2013). However, Žák, Struhár, Janoušek, and Ondráček (2020) found that higher pressure in the last 0.5–1.0 s contributes to significantly higher aiming stability. In other words, a large difference between the pressure required to trigger and observed during testing at these timestamps leads to greater destabilization of the rifle.

We can state that the first and second types of descent processing are preferable to the third, in which the athlete reacts to the appearance of a fly under the centre of the target with a sharp movement of the finger. This, in turn, can lead to sensorimotor discoordination, which will subsequently lead to a shift in the rifle's aiming devices relative to the target, and the result of which, in the worst case, will be a miss.

Discussion

An increase in the smoothness in the muscular effort of the index finger from the beginning of aiming to the production of the shot, when processing the trigger, is observed in highly qualified biathletes, as well as in athletes specializing in shooting. Biathletes are less qualified; their efforts are distributed unevenly, which often causes different amplitudes of the weapon barrel vibrations, which results in poor shooting quality. In this regard, it is not recommended to use the third type of descent processing when shooting.

It is important to feel the movement and pressure of the finger on the trigger (differentiation of forces) with various changes in the state of the shooter caused by physical exertion and affecting the increase in vibrations of the weapon. For example, when shooting, use a trigger tension of 100 g can be used, which shows the best sensitivity and differentiation at a tension of 400 g. Therefore, it is necessary to select such a descent tension, in which the athlete shows the best indicators of sensations or differentiation of efforts, tested instrumentally. In our case, this is confirmed to some extent by the standard spread that can be observed in Figures 2 and 3 (represented by dotted lines). So, for example, in Athlete 2, when shooting after a load, it increased, on average, by 5.1%.

It is noteworthy that when athletes used the first two types of trigger handling, the pressure value at the time "TP" exceeded the required for the production of the shot, on average, by 31%. Simultaneously, the athlete who used the third type of shot exceeds it, on average, by 77%, which is also a rather negative factor, since it can potentially cause undesirably more significant fluctuations in the weapon after the shot. This, in turn, will require him to make additional efforts to repay them.

It should be noted that our findings are significantly different from those obtained by other researchers. This is confirmed by the results of several studies (Sattlecker, Müller, & Lindinger, 2009; Žák et al., 2020). In accordance with them, the level of pressure on the trigger for boys and girls for 1 s before the shot is about 75% or even more, and for juniors 85%, and then only continues to grow. In this regard, the question arises as to what this fact may be due. We suggest that it is connected with certain features of the organizational and methodological aspects of the training process.

Our experiment yielded a sufficiently informative picture of the triggering quality. It allows us to classify different triggering stereotypes and further analyse which of them can be most effective for athletes choosing a particular shooting style. It was found that even after targeted training sessions, the technique of processing the trigger in accordance with the key phases of athletes can differ significantly.

The composition of the phase structure of the shot is determined: the initial increase in force (I); the intermediate phase (II), in which the pressure can be constant or change; the trigger pull phase (III). In accordance with the phases selected, three types of processing descent: the first is characterized by a continuous, linear pressure increase; the second is determined by the presence of plateau pressure; a third pulse, wherein the pressure on the trigger increases significantly in a very short period.

In such conditions, there are methodological issues related to the selection of adequate training tools and methods aimed at improving the technique of handling the trigger. An important condition that must be met is the presence of a feedback system. However, although in the world of biathlon and shooting sports there are already tools that can provide it (for example, "SCATT"), we see the prospect of developing more advanced hardware and software systems and organizing their work not only in the laboratory but also in natural conditions (on the shooting range). This expansion of functionality will help solve problems related to improving proprioreceptive sensations associated with the differentiation of efforts applied by a biathlete to the trigger against the background of physical activity.

In our opinion, the most optimal way to organize feedback on the amount of pressure in this case is the glasses used by the athlete. This, in turn, imposes very serious requirements on the design features of the recording system: weight and overall dimensions. It is also important to ensure a sufficiently high level of measurement accuracy.

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Conflict of Interest
The authors declare that there is no conflict of interest.

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