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TIMING OF THE TRIGGERING ACTION OF SHOOTING IN RELATION TO THE CARDIAC CYCLE

P. HELIN, MSc, T. SIHVONEN, MD and O. HÄNNINEN, MD, PhD
Department of Physiology, University of Kuopio, Finland

ABSTRACT

The purpose of this study was to verify the timing of triggering in relation to the cardiac cycle in shooting. The test subjects were six Finnish rifle and pistol champions as well as three beginners at shooting. The electrical activity of the trigger finger muscle (m. flexor digitorum superficialis; surface electrodes) and the heart cycle were fed into a two-channel x-t recorder. The movements of the gun were recorded using a laser technique and, at the same time, cardiac cycles were also monitored. Results showed that the champion shooters triggered during diastole whereas the beginners triggered both during diastole and systole. The results of those beginners triggering during diastole were better than those triggering during systole.

Key words: Shooting, Cardiac cycle, EMG, Cardiac awareness.

INTRODUCTION

According to coaches, accurate shots are triggered during the resting phase of the cardiac cycle, i.e. during the ventricular diastole. However this has been difficult to prove. During systole the whole body makes a small jerk, causing a problem in tasks which require careful aiming such as shooting. The movements can cause sudden misalignment of the rifle, the distance multiplying error.

In shooting training special attention is paid to the heart rate and its control. In the healthy heart the duration of systole and diastole depends on the heart rate; the period of systole decreases markedly less than diastole with increase in heart rate (Guyton, 1981). Champion shooters are able to sense their heart beats. However, the control of the internal body functions, like heart rate is not easy. In several studies negative results have been obtained in attempts to control the heart rate (Brener, 1977; Katkin et al, 1982; Montgomery et al, 1984; Jones et al, 1985). However, coaches believe that shooters' biofeedback of the heart beat becomes automatic and therefore they learn to trigger during the optimal time with the aid of a specialised reflex.

It has previously been difficult to study simultaneously the triggering of shots and the cardiac cycle in competition. The new electromyographic (EMG) technique (Remes et al, 1984) permits such analysis. Results of the present study indicate that good shots are indeed triggered during diastole.

TEST SUBJECTS AND METHODS

The test subjects were six Finnish champion rifle (n = 4; 2 male, 2 female), and pistol (2 male) shooters, aged 20-53 years, and 3 rifle-shooting beginners (male), aged 20-24 years. They had undergone shooting training for 5-30 years and 1-2 years, respectively. In this study each subject fired 20 shots which were recorded during a training camp, under conditions similar to those in a competition (15°C, cloudy weather with some wind).

The measurements of electrical activity in the triggering muscle and the heart were performed with two similar, pocket size EMG analysers (ME-10 RI, Mega Electronics Ltd., Kuopio, Finland) (Fig. 1) using disposable ECG surface electrodes (diameter 15 mm, Christian Nissen, Helsinki, Finland). The fully rectified, integrated, band (20-600 Hz) EMG (IEMG) (Remes et al, 1984) was recorded from the trigger finger muscle (the flexor digitorum sublimis to the index finger). The measuring electrode was attached, after palpation, about 5 cm above the wrist and the reference electrode applied to the 7th cervical spinous process (the first EMG analyser). When the reference electrode was attached at a distance of 10 cm from the measuring electrode, the IEMG level was slightly higher than when placed upon the 7th cervical process. The ECG was recorded with the second EMG analyser using the above reference electrode and by attaching a second electrode (measuring) at the distal end of vastus lateralis muscle (the same distance from the 7th cervical process as the electrode on the triggering muscle). The ground electrode, for removal of 50 Hz noise from the environment, of both devices was placed on the upper trapezius muscle. The time constant (integration time) of both EMG analysers was 0.1 s i.e. the delay in the recordings of both devices was the same. The EMG and ECG signals were fed into a two-channel x-t recorder (Servogor 120, Goertz Electro GmbH, Vienna, Austria), which was calibrated in relation to the time axis (Figs. 1 and 4).

One peak corresponding to the QRS-complex could clearly be seen in the ECG signal measured with the aid of

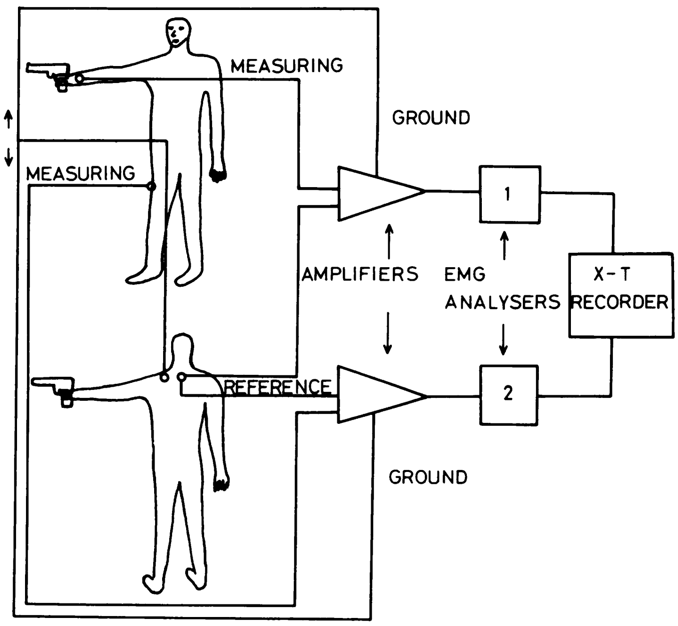

Fig. 1: Schematic presentation of the measuring system for triggering in relation to the cardiac cycle. For explanation, see Methods.

Address for correspondence:
Dr. O. Hänninen
Department of Physiology
University of Kuopio
PO Box 6
SF-702/1 Kuopio
Finland

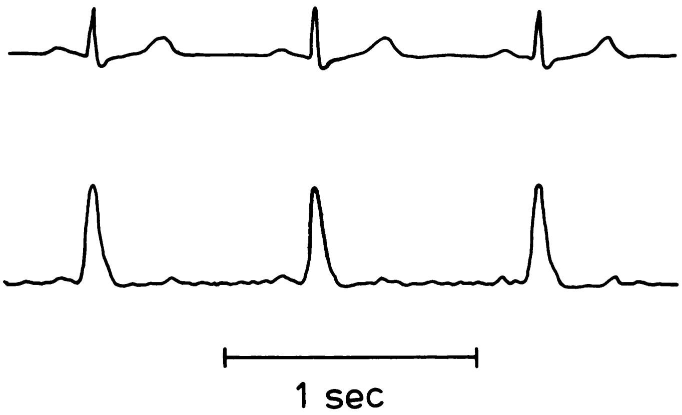

Fig. 2: Comparison of electrocardiograms (Standard lead 2) registered Mingograf minor 3 with paper speed of 50 mm·s⁻¹(upper curve) and with EMG analyser (Me-10 RI) recorded with Animex Recorder at the same speed (lower curve).

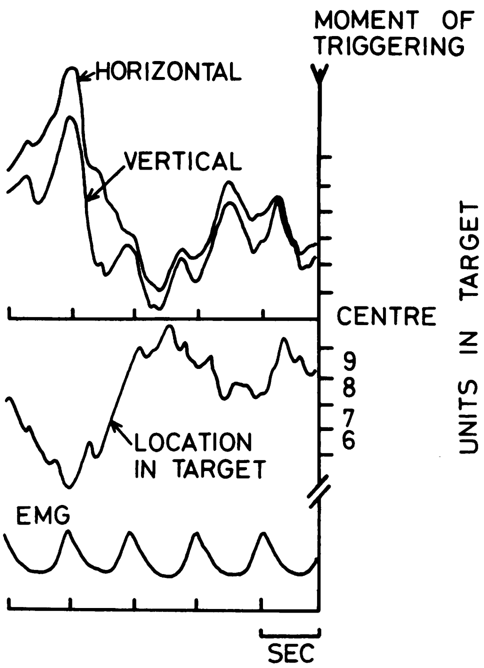

Fig. 3: The movement of the laser "bullet" during aiming in the standing position standing in rifle shooting during the last 5 seconds measured by the Noptel ST-1000 laser device. The horizontal and vertical movements, the distance from the centre of the target, and the ECG registration are shown. The triggering time and the result during the aiming and triggering are seen from the figure. Cardiac cycles are observed in the movmements of the laser "bullet" together with larger oscillations of the body.

the EMG analyser (Figs. 2 and 4). Verification of the ECG was performed in parallel to laboratory conditions using recordings from a traditional ECG instrument (Fig. 2). The movements of the gun were followed with a laser device attached onto the gun barrel (Noptel ST-1000, Oulu, Finland). The horizontal and vertical movements of the gun and the distance of the laser "bullets" from the centre of the target were recorded (Fig. 3).

RESULTS AND DISCUSSION

The recording of electrical activity from m. flexor digitorum superficialis of the triggering finger and the heart proved to be a reliable and simple method to study the timing of shots in shooting in relation to the cardiac cycle (Figs. 4 and 5). The electrode must, however, be attached exactly upon the muscle mass contributing to the triggering (palpation). The

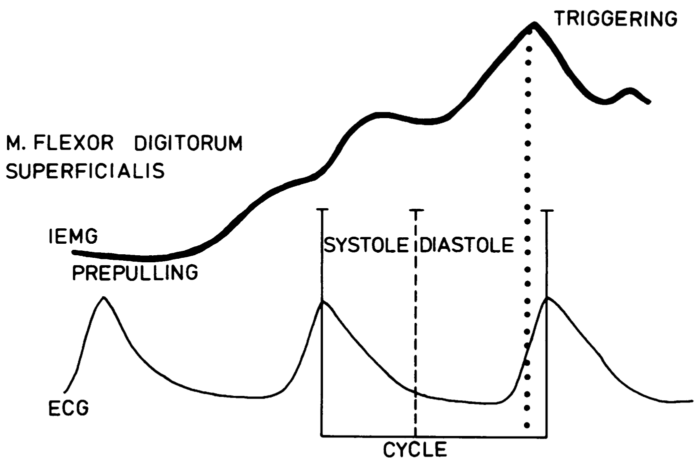

Fig. 4: The timing of triggering (IEMG, upper curve) in relation to the cardiac cycle also recorded with the aid of an EMG analyser (lower curve). The triggering was measured from the IEMG of m. flexor digitorum superficialis of the trigger finger. (For further explanations see Fig. 1). The highest peak of the IEMG curve indicates the time of the triggering. It is preceeded by a prepulling indicated by a preliminary increase in the IEMG. The highest peak of the lower ECG curve is the QRS-complex. The beginnings of two successive systoles have been marked by solid lines. The approximate starting time of diastole has been indicated by a broken line.

distance between the measuring and reference electrodes did not affect the recording of electrical activity. This is understandable, since the shoulder and arm must be stabilised in shooting. Pre-pulling and triggering increased the electrical activity only in m. flexor digitorum superficialis (Fig. 4). For the study of the cardiac cycle the EMG analyser was much easier to use in field conditions, and cheaper, than the conventional ECG device and gave the same results (Fig. 2).

The results obtained suggested that under simulated competition conditions the champion level shooters had slower heart rates during triggering than the beginners. Furthermore, experienced male rifle shooters had slower heart rates than females (Table I).

TABLE I

Types of shooters, their career lengths, heart rates (beats·min⁻¹) and systole-diastole relationships (%) calculated from the ECG, at the time of triggering in simulated competition conditions.

Shooters	Subject no.	Age (yrs)	Shooting career (yrs)	Heart rate at time of triggering (beats.min⁻¹)	Systole/ diastole %
Champion level					
Smallbore rifle	1	34	15	52-55	22-23/78-77
	2	38	22	65-68	27-28/73-72
	3 F	24	8	85-87	35-36/65-64
	4 F	21	6	89-91	37-38/63-62
Centrefire pistol		25	8	90-93	38-39/62-61
Rapid fire pistol		53	32	70-75	30-31/70-69
Beginners					
Smallbore rifle	1	20	1	90-100	38-41/62-49
	2	21	2	88-92	37-38/63-62
	3	24	2	98-102	40-42/60-58

F denotes a female subject

The results showed that the champion rifle shooters almost consistently (80 shots analysed) fired during the ventricular diastole (Figs. 4 and 5), whereas the beginners fired (60 shots analysed) either during systole or during

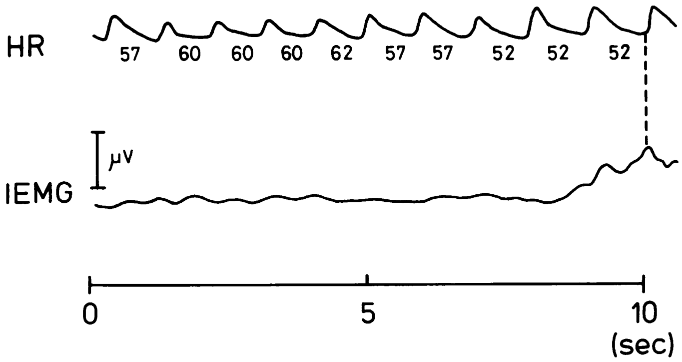

Fig. 5: The heart rate (HR) and IEMG of m. flexor digitorum superficialis in rifle shooting before and at the time of triggering for a European champion. For explanations see Fig. 1 and Methods.

TABLE II

The timing of triggering in shooting recorded with the aid of the IEMG of the triggering muscle (m. flexor digitorum superficialis) in relation to cardiac cycle in champions and beginners of shooting.

Shooters	Subject no.	No. of shots	Triggered during diastole	Result 20 shots	Result during diastole (mean)	Result during systole (mean)
Champion level						
Smallbore rifle	1	20	20	200	10.00	—
	2	20	20	200	10.00	—
	3 F	20	20	196	9.90	—
	4 F	20	19	197	9.89	9.00
Centrefire pistol		20	19	199	10.00	9.00
Rapid fire pistol		20	17	198	9.94	9.67
Beginners						
Smallbore rifle	1	20	14	162	8.86	6.33
	2	20	16	182	9.38	8.00
	3	20	11	168	9.00	7.67

F denotes a female subject

diastole (Table II). The probability of the triggering movement occurring during diastole was about 60% or 12 from 20 shots at a heart rate of between 90 and 100 beats·min^{-1}. The actual results obtained (Table II) from the beginners varied from 11 to 16 out of 20, i.e. as expected assuming a random triggering. The scores of the champion level shooters were superior to those obtained by the beginners. The beginners also achieved better scores when they triggered during diastole rather than to systole.

It was remarkable that, during rapid firing, the champion pistol shooter triggered during the diastole in 17 shots out of 20 considering the shooting took place in 6 s intervals (5 shots each). The centrefire pistol shooter triggered nearly as successfully during diastole as the rifle shooters (Table II). The best timing of triggering seems to be during late diastole, when the relaxation of heart has lasted for nearly the longest possible period (Figs. 4 and 5). The comparison of cardiac cycles with the movements of the gun, followed with the laser technique, indicated that the triggering took place between the jerks caused by the heart, i.e. during diastole (Fig. 3).

If the oscillations of the laser "bullet" are examined closely when the rifle shooter is standing (Fig. 3), it can be seen that the peaks of the horizontal and vertical components follow on about 0.2 s after the peak (QRS-complex) in the electrical cardiac cycle. This agrees with the known delay between the R-wave of the ECG and maximum systolic pressure. From Fig. 3 it can also be seen that the peak wave tends to jerk the aiming arm both upwards and outwards, since both vertical and horizontal components are consistently equally high. The fact that, when standing, aiming is difficult can also be recognised from the slower high- amplitude oscillations (Fig. 3).

The results obtained confirmed the old practical assumption of coaches that shooters learn in time consistently to avoid jerking caused by heart contraction and to trigger in diastole. This may explain why many champion shooters are much older than beginners and have as a result a lot of shooting experience (those studied here had been shooting for 5-30 years). Learning to shoot is apparently difficult and takes time as does the development of the proper reflex functions. Fully developed reflexes obviously do not reach a conscious level, since even rapid-fire triggering nearly always takes place in diastole. This probably also explains the deviation of our results from earlier studies on awareness of heart beat (Katkin et al, 1982; Jones et al, 1985). The discriminatory training of the heart beat of the subjects in their studies, however, had lasted for a much shorter time than for the shooters' in the present study (Table I). The results for the beginners in this study agree with observations obtained in the earlier reports.

Before shooting, the heart rate clearly decreased in the champion rifle shooters by 7 to 13 beats·min^{-1} (Fig. 4) and in the beginners by 3 to 6 beats·min^{-1}. This is dependent on the holding of breath which is a normal preparatory measure for triggering in shooting causing a sinus arrythmia through vagal stimulation (Hirsch and Bishop, 1981). The decreased heart rate may also result from the shooter's autogenic relaxation before shots (Helin and Hänninen, 1985).

The present results do not clarify how the sensing of the heart beat occurs. It could take place either in the hand (tightly around the gun) or visually by seeing the jerks of the barrel which are caused by heart beats or by a combination of both. Visual signals have perhaps the primary role, since the shooter is aiming before the triggering. The pre-pulling is performed to minimise the need for muscular contraction during the final action. Sensing of pulse waves in the hand may be the final determinant in pulling the trigger at the right time.

The rules of the International Shooting Federation state that the attachment of any kind of detectors onto the gun is forbidden (e.g. Suomen Ampujainliitto, 1985). The IEMG-method developed in the present study can be, and has been, used in international competitions. The rules also prohibit the use of beta-blocking drugs as these can affect shooting success by prolonging diastole and reducing muscle tremor. However coaches believe that all shooters do not benefit from these drugs, since fainting can occasionally occur during competition.

From the present studies it can be concluded that the champion shooters are not only able to modify their heart rate, but are also able to trigger in diastole instead of systole. They develop a heart-skeletal muscle reflex during their years of training. The paper describes an easy and practical method for determining the timing of triggering in relation to the cardiac cycle in field conditions. The method will also help in the training of shooters. If the heart cycle is used to generate autitive stimuli, it should be easier for shooters to learn how to avoid the disturbing jerk of the heart beat on firing.

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