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SNIPERS' SHOOTING CONTROL CHART

Reviewer: Lubomír POPELÍNSKÝ

A b s t r a c t :

In this article is presented the using of shooting control chart during snipers´ shooting practice. The proposed method of statistical control of snipers´ shooting is original and according to the authors´ opinion it can contribute to the improvement of controlling military and police snipers´ training.

1. Introduction

The current growth of the number of terrorist attacks requires:

- the improvement of snipers' training,
- new methods of their training,

- new evaluation methods of snipers' capability and readiness to reliably hit the specified target anytime, as well as
- statistical control of snipers´ shooting practice.

We are bringing a new method of statistical control of snipers´ shooting practice. According to our opinion it can contribute to the improvement of controlling military and police snipers´ training.

The sniper has to hit a live target by the first shot. The hit must be directed to a part of body specified in advance. The firing is basically conducted in two ways:

- firing intended to only wound the person and to restrict his/her movement or other activities;
- firing intended to reach the lethal effect by hitting vital parts of human body.

To enable the only shot to immediately stop the conscious activity of a live target, the sniper must hit, if possible, the centre of muscular tension, movement co-ordination and balance keeping. The size of this part of CNS can be limited by a circle 80 mm in diameter [1].

The value of ϕ 80 mm represents the basic etalon for evaluating the accuracy of sniper's shooting ($T = \phi\, 80$ mm).

2. Shooting process variability

During sniper's shooting, a large number of factors influence the trajectory of the projectile, which results in the fact that the point of hit does not fully correspond with the target point.

Each shooting process shows a kind of variability, the source of which is, besides the sniper, the weapon itself (sniper rifle), the cartridge used, as well as the importance of the situation and the environment in which the shooting takes place (temperature, air humidity, atmosphere optical qualities, wind speed and direction etc.) – see Figure 1.

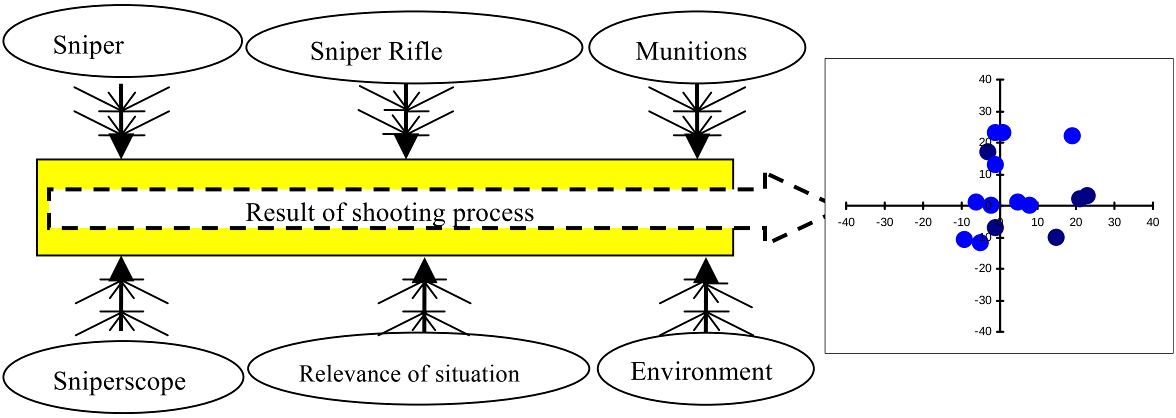


Figure 1 Sources of shooting process variability

If we mark the coordinates of sniper's hits from the distance d by symbols ${}^{d}x$ and ${}^{d}y$, we can determine the value of hit radius ${}^{d}r$ (see Figure 2) that represents the distance of the hit from the target point (centre of gravity of the prescribed target area):

$$ {}^{d}r = \sqrt{{}^{d}x^{2} + {}^{d}y^{2}} \quad (1) $$

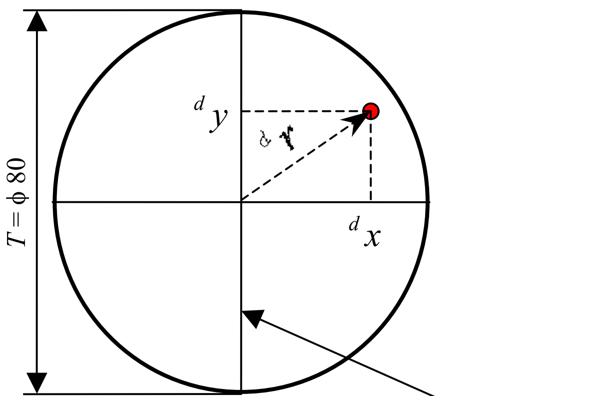


Figure 2. Hit radius ${}^{d}r$

Variability of sniper's shooting at the distance d is being determined by an interval in which, with assigned probability, all values of sniper's hits occur. If the shooting process variability occurs in a normal distribution, we can determine the interval in which, with assigned probability, all values of sniper's hits occur by means of multiples of standard deviation ${}^{d}s_{r}$.

For the evaluation of sniper's shooting process it is essential to determine the standard deviation ${}^{d}s_{r}$ in such a way that each hit is evaluated as a result of sniper's first shot. In practice, we first of all determine the difference between the radii of two consecutive first hits. We determine so-called moving range [3] for hit radii ${}^{d}R_{k_l}$:

$$ {}^{d}R_{k_l} = \left| {}^{d}r_l - {}^{d}r_{l+1} \right|, \tag{2} $$

where ${}^{d}r_l$ is the radius of *l-th* hit at the distance d,

${}^{d}r_{l+1}$ is the radius of *(l + 1th)* hit at the distance d.

It means that firstly, after the second hit we subtract the second hit radius from the first hit radius, then the third from the second etc. Using the average moving range we will estimate the standard deviation of a certain sniper's hit set from evaluated n hits:

$$ {}^{d}s_{r} = \frac{\overline{{}^{d}R_{k}}}{d_2} = \frac{\overline{{}^{d}R_{k}}}{1.128}, \tag{3} $$

where d_2 is so-called Hartley's conversion constant whose magnitude for moving range of two values is 1.128 [3],

$\overline{{}^{d}R_{k}}$ is an average moving range calculated from the relation:

$$ \overline{{}^{d}R_{k}} = \frac{\sum_{l=1}^{n-1} {}^{d}R_{k_l}}{n-1}, \tag{4} $$

where n is a number of hits.

In practice we can interpret the value of standard deviation in such a way that the majority of hits does not deviate from the target point by more than one standard deviation ${}^{d}s_{r}$. Low value of standard deviation ${}^{d}s_{r}$ means small variability of shooting and a high accuracy of sniper's shooting. On the contrary, low variability means a low accuracy of sniper's shooting.

3. Shooting control chart

Target area (e.g. a target disc of 80 mm in diameter) as a source of information used in training snipers and for deciding about their employment in the action is not quite optimal. Data of practice target disc hits do not provide a satisfactory answer to a question that is asked by the mission commander before making the decision: "does the employment of just this sniper in a particular situation ensure a 100% fulfilment of the task?" Evaluation of hit numbers from practice target discs of various types does not give a precise answer to the degree of risk of failure in fulfilling the task by one (the first) shot.

Sniper's training must result in such capability of shooting when target hit is almost certain. This can be achieved when shooting has a very low variability and is "centred" to the target point. Practice organization must ensure all decisive factors that can affect shooting accuracy (Figure 1) to be mastered by the shooter on such a level that no factor can prove to be decisive (dominant) for the results of shooting.

It means that shooting dispersion may be influenced by a number of concrete reasons, nevertheless, none of which may exceed the specifically significant degree that could cause enhancement of shooting dispersion. In other words, the shooter must ensure that all the factors participating in shooting accuracy in accordance with Figure 1 (sniper, weapon, ammunition, sniperscope, environment, and significance of the situation) contribute in a degree that can be regarded, from the viewpoint of shooting results, only as random effects.

A suitable tool for controlling shooting practice can be the shooting control chart designed by the authors. The shooting control chart enables quickly to recognize and identify changes (failures) in the process of sniper's shooting.

The shooting control chart is a graphical representation of the process of shooting in time (Figure 3).

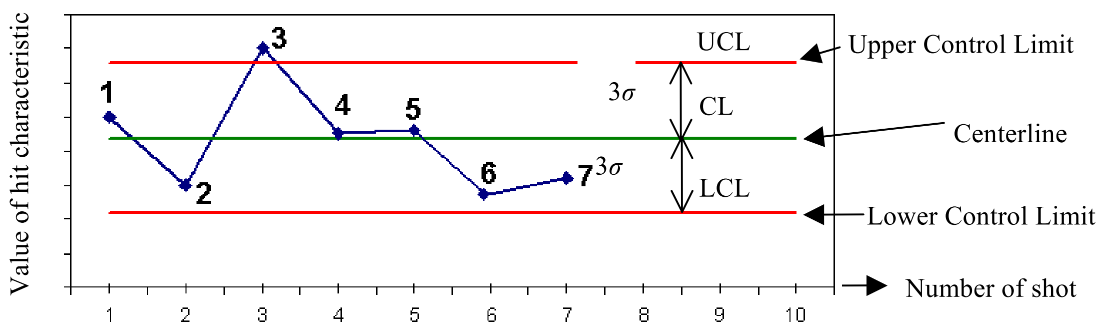


Figure 3 Principle of shooting control chart

In the shooting control chart are recorded results of the sniper's shooting (values of hit) in a chronological sequence.

In the shooting control chart are also illustrated so called regulation limits. The distance between upper control limit and lower (bottom) control limit defines a space for inherent variability of sniper's shooting.

In the shooting control chart the distance between both regulation limits is six standard deviations of hit value (further only 6σ) and both regulation limits are 3σ from the central line. The setting of regulation limits at the distance of $\pm 3\sigma$ ensures that 99.73 % of all hit values will be situated inside the regulation limits. It means that by training a sniper reached a level where there is no influence of a dominant factor which could negatively influence the result of his shooting. The influence of all the factors affecting the hit can be regarded only as random.

If the hit value appears outside the regulation limits (see shot No 3), it is necessary to take measures on the side of the shooter which decrease his variability of shooting. In this case the influence of a shooting factor prevailed during sniper's shooting. It is necessary to disclose it and to eliminate its undesirable effect.

If we select hit radius ${}^{d}r$ as a studied characteristic, the shooting control chart will be formed by a pair of control charts – one chart for individual values of hit radius ${}^{d}r_i$ and the second one for their moving range ${}^{d}R_{k_i}$.

3.1 Shooting control chart for hit radius ${}^{d}r_i$

Individual values of hit radius ${}^{d}r_i$ (i = 1, 2, ... n) are recorded into this type of shooting control chart. The central line is therefore equal to arithmetic mean $\overline{{}^{d}r}$ of all measured values.

$$CL_{{}^{d}r} = \overline{{}^{d}r} = \frac{\sum_{i=1}^{n} {}^{d}r_i}{n} . \tag{5}$$

Upper and lower control limits for ${}^{d}r_i$ can be calculated from following relations [3]:

$$UCL_{{}^{d}r} = \overline{{}^{d}r} + 2{,}66\,\overline{{}^{d}R_k} , \tag{6}$$

$$LCL_{{}^{d}r} = \overline{{}^{d}r} - 2{,}66\,\overline{{}^{d}R_k} , \tag{7}$$

where $\overline{{}^{d}R_k}$ is an average moving range which can be calculated from relation (4).

3.2 Shooting control chart for moving range ${}^{d}R_{k_i}$

Shooting control chart for moving range of hit radii is intended for showing the values of individual moving ranges ${}^{d}R_{k_i}$ - relation (3) and tests the changes of variability of sniper's shooting during his/her training.

We can use relation (8) for determining upper control limit in the shooting control chart for moving range:

$$UCL_{{}^{d}R_{k}} = 3{,}267\,\overline{{}^{d}R_{k}}\,. \tag{8}$$

The value of centre line $CL_{{}^{d}R_{k}}$ equals the size of an average moving range $\overline{{}^{d}R_{k}}$ which can be calculated from relation (4).

Lower control limit for moving range is equal to zero [3]:

$$LCL_{{}^{d}R_{k}} = 0\,. \tag{9}$$

On the next page is shown a possible form of a sniper's shooting control chart for shooting evaluation during training.

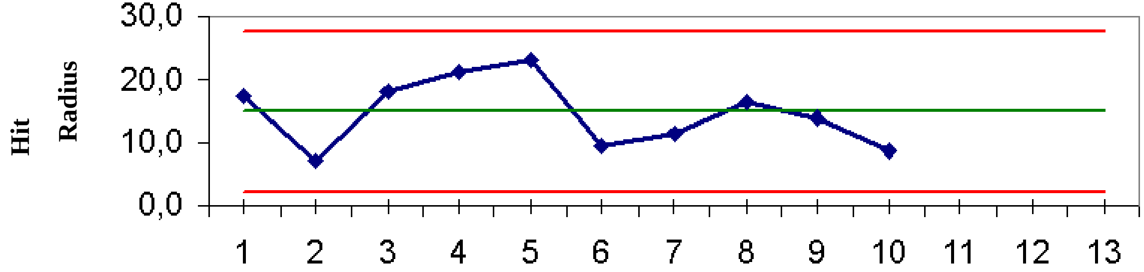
Table 1a

Shooting control chart

SHOOTING CONTROL CHART			
Sniper: *G*	***Weapon:****7.62 SVD No 522*	***Sniperscope:****PSO-1 No 25522*	***Distance:*** *100 m*
Ammunition: *M59* ***Manufacturer:*** *S&B* ***Year:*** *2003* ***Series:****27*	***Range:*** *L218*	***Stand:*** *No 1*	

MAP VALUE

Shooting control chart for hit radius



Shooting control chart for moving range

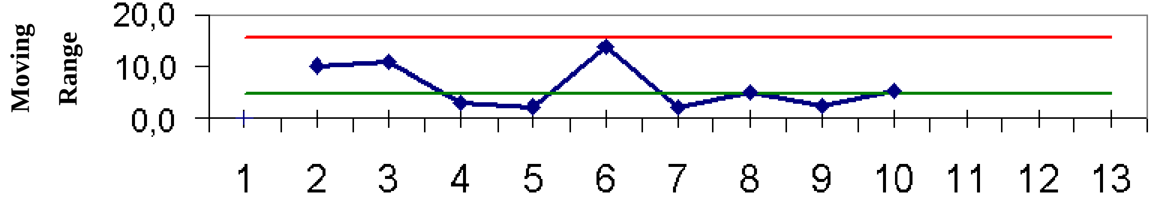


Table 1b

Shooting parameters

Shoot Number		Unit	1	2	3	4	5	6	7	8	9	10	11	12	13
Hit parameters	${}^{100}x$	mm	-3	-1	15	21	23	5	-3	16	12	-7			
	${}^{100}y$	mm	17	-7	-10	2	3	8	11	3	7	-5			
	${}^{100}r$	mm	17.3	7.1	18.0	21.1	23.2	9.4	11.4	16.3	13.9	8.60			
	${}^{100}R_k$	mm	-	10.2	11.0	3.1	2.1	13.8	2.0	4.9	2.4	5.3			
Date (Year 2006)		-	22/11	22/11	22/11	22/11	22/11	23/11	23/11	23/11	23/11	23/11			
Time		-	10:45	11:30	12:10	13:05	13:50	9:46	10:07	10:38	11:01	11:44			
Distance		1	3	3	3	3	3	3	3	3	3	3			
Direction		1	0	0	0	0	0	0	1	1	1	1			
Cartridge Temp.		°C	10	11	11	11	11	10	10	10	11	11			
Outside Temp.		°C	4.3	4.2	3.9	3.9	4.4	2.9	3.1	3.8	4.0	4.4			
Outside Humid.		%	88	89	89	87	84	64	65	63	60	57			
Wind	**Dir**	-	W	W	W	W	W	SE	SE	SSE	SE	SSE			
	Speed	$m.s^{-1}$	2.2	3.1	2.2	2.2	1.8	4.9	3.6	5.4	4.9	4.9			
	Run	km	2.01	0.94	0.67	0.67	0.54	0.30	0.21	0.32	0.30	0.30			
Solar Rad		$W.m^{-2}$	69	83	43	100	114	167	229	264	243	234			
Solar Energy		Lang.	1.48	0.59	0.31	0.72	0.82	0.24	0.33	0.38	0.35	0.34			
Rain Rate		$mm.h^{-1}$	0	0	0	0	0	0	0	0	0	0			
Remedy		-	-	-	-	-	-	direct.	-	-	-	-			

Table 1c

Shooting Capability Evaluation	$^{100}\overline{x} = \sum_{i=1}^{n} {}^{100}x_i = \sum_{i=1}^{10} {}^{100}x_i = 7.8mm$ $^{100}\overline{y} = \sum_{i=1}^{n} {}^{100}y_i = \sum_{i=1}^{10} {}^{100}y_i = 2.9mm$ $^{100}\overline{r} = \sum_{i=1}^{n} {}^{100}r_i = \sum_{i=1}^{10} {}^{100}r_i = 14.63mm$	$\overline{^{100}R_k} = \frac{\sum_{l=1}^{n-1} {}^{100}R_{k_l}}{n-1} = 6.09mm$ $^{100}s_r = \frac{\overline{^{100}R_k}}{1,128} = 5.4mm$	$^{100}c_s = \frac{40 - \overline{^{100}r}}{3.{}^{100}s_r} = 1.57$
Proposed Measures	without remedy measures – shooting process - capable		

In the bottom part of the shooting control chart (see above) is carried out an overall evaluation of capability of shooting process within a given period (after 10 test shots) by means of an index of sniper's shooting capability ${}^{100}c_s$ [1]. The index of shooting capability introduced by the authors enables to express by a single number the capability of a sniper to hit the required target.

Sniper's shooting capability index at the distance of 100 m ${}^{100}c_s$, as the only number for the evaluation of his/her shooting process capability, is defined by the following relation [1]:

$$ {}^{100}c_s = \frac{40 - \overline{{}^{100}r}}{3.{}^{100}s_r}, \tag{10}$$

where $\overline{{}^{100}r}$ is the average hit radius for the given distance of 100 m calculated from relation:

$$ \overline{{}^{100}r} = \frac{\sum_{i=1}^{n} {}^{100}r_i}{n}. \tag{11}$$

The value of ${}^{100}c_s$ ${}^{d}c_s \geq 1.00$ means that the sniper is competent for the given task and the value of ${}^{d}c_s < 1{,}00$ expresses that the sniper is not competent for fulfilling the given task (more in detail see [2]).

4. Possibilities of using the shooting control chart in training

The shooting control chart can be used as a suitable diagnostic tool for the assessment of both stability and capability of the sniper's shooting. Individual hits marked in the shooting control chart represent sniper's self-regulatory ability for the certain distance shooting.

The shooting control chart of the practice shooting at the distance of 100 m of three snipers is shown in the Figure 4.

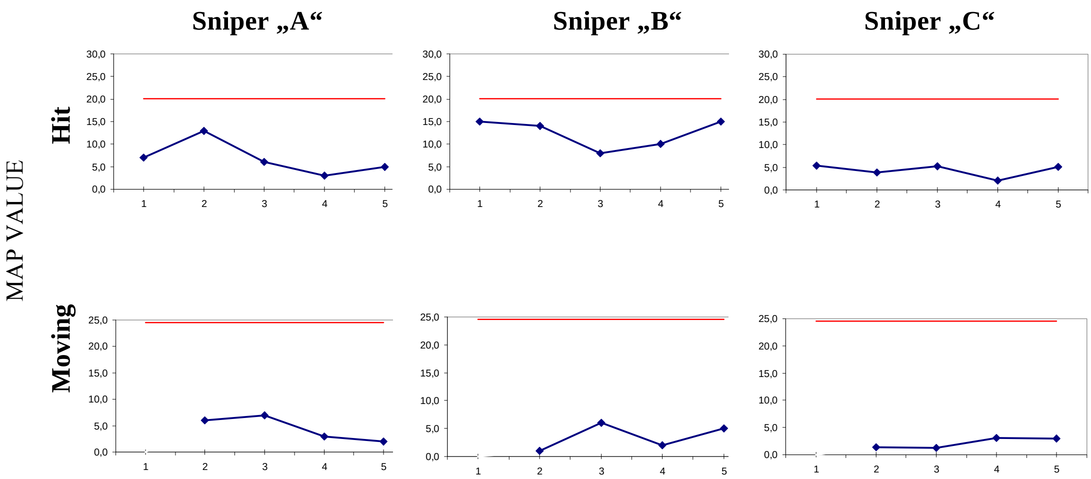


Figure 4 Evaluation of sniper’s shooting process at the distance of 100 m

The best results have been achieved by the sniper "C". His shooting control chart evidently demonstrates the lowest variability of all three snipers during the shooting process. His/Her shooting process also shows necessary stability of shooting results, which is demonstrated by his stable value trends in the shooting control chart (both for hit radius and moving range). The values of hit radius are very low (in average less than 5 mm). The standard deviation of hit radii for this sniper is extremely low (less than 2 mm). The level of shooting capability of this sniper is several times higher than that of the two other snipers.

Snipers "A" and "B" also achieve required shooting process capability at the distance of 100 m. The values of hit radius are higher than those of the best sniper "C" (they are not higher than 15 mm with sniper "B" and 10 mm with sniper "A"), but they are situated inside control limits.

Sniper "C"´s shooting control chart demonstrates his/her perfect training and his capability of eliminating almost all decisive factors that can affect shooting accuracy at the given distance. These factors are mastered by the sniper on such a level that none of them manifests itself as a dominant and decisive factor for shooting results. It means that the shooting dispersion of sniper "C" may be influenced by a number of specific factors – see Fig. 1, none of which is prevailing (dominant) and in shooting process they show themselves only through random effects. The random effects are demonstrated by means of the shooting control chart very well and clearly.

The shooting control chart also enables to demonstrate trends in individual snipers´ development in the course of training, e.g. their improvement or deterioration (up to documenting the state that led to his/her expelling from training). In Fig. 5 is a sniper’s shooting chart with a new ammunition.

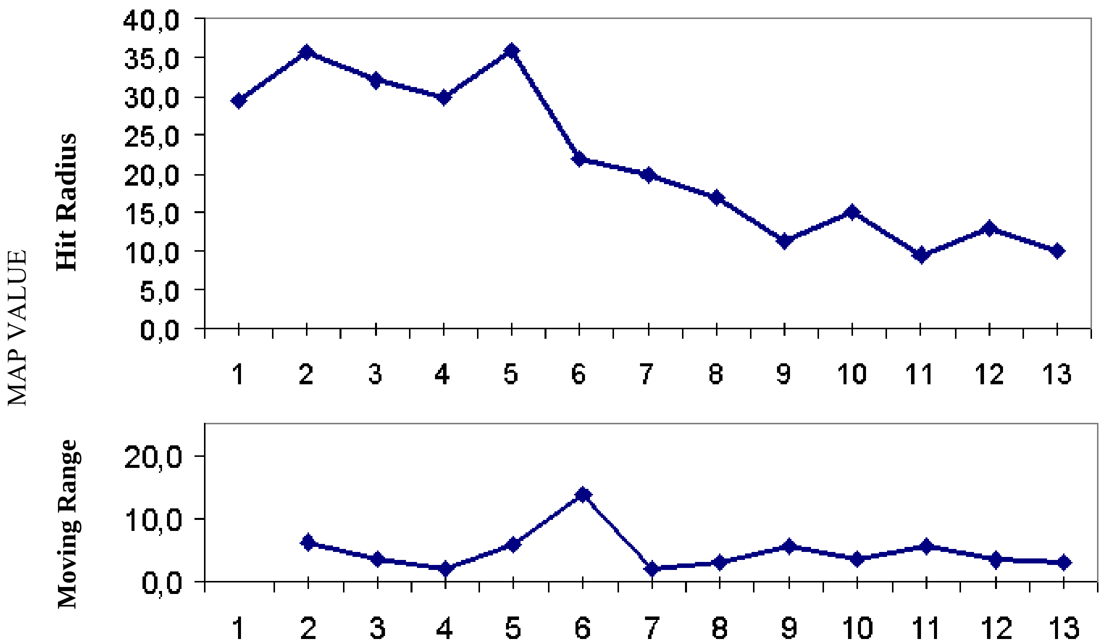


Figure 5 Shooting control chart when new ammunition is used

In the left part of shooting control chart you can see that first shots using new ammunition exceeded the upper control limit and shooting process is incapable in this part.

Figure 6 shows a shooting control chart for the hit radius which is divided into three arts and presents a positive (developmental) trend of improvement of sniper's performance.

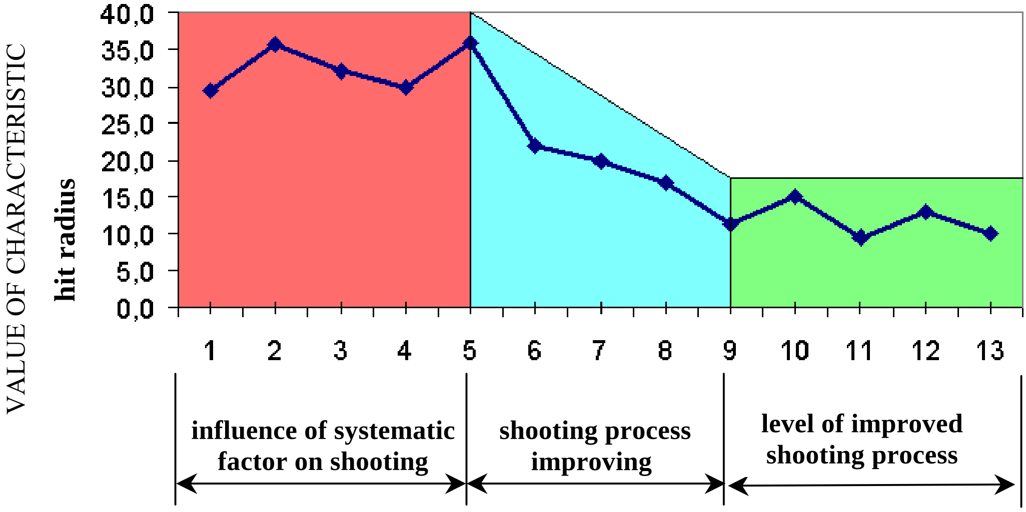


Figure 6 Improving of shooting process

In Figure 6, in the first part of the shooting control chart there are recorded high values of radius of hits (30-35 mm) caused by using a new type of ammunition with different ballistic properties. The shooting control chart convincingly recorded the influence of systematic factor, i.e. the using of a new type of ammunition, and the values of hit radii exceed the values of sniper "B" from Fig. 4 several times.

The second part of the shooting control chart depicts the process of shooting improvement of the sniper using a new type of ammunition. The values of hit radii gradually lower to a standard level of sniper "B" (10-15 mm).

The third part of the shooting control chart records the level of a new stable state of shooting process of the sniper. The level of hit radii reaches here the level comparable with the stable and capable shooting process of sniper "B" from Fig. 4.

5. Conclusion

The shooting control chart provides a clearly organized illustration of training shooting process of snipers. Individual hits inside control limits reflect the ability of the sniper to hit the target by the first shot.

Using shooting control charts enables not only to effectively control the process of training, but offers a possibility to obtain a good knowledge about theoretical background of shooting process of any sniper.

The shooting control chart can successfully monitor trends in development of individual snipers and enables to take effective measures to improve their performance and is a suitable tool for documenting and evaluating snipers´ ability to fulfil their tasks.

R e f e r e n c e s

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