β-Blockade used in precision sports: effect on pistol shooting performance

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KRUSE, PETER, JØRGEN LADEFOGED, ULLA NIELSEN, POUL-ERIK PAULEV, AND JEAN PIERRE SØRENSEN. *β-Blockade used in precision sports: effect on pistol shooting performance.* J. Appl. Physiol. 61(2): 417–420, 1986.—In a double-blind crossover study of 33 marksmen (standard pistol, 25 m) the adrenergic β_1-receptor blocker, metoprolol, was compared to placebo. Metoprolol obviously improved the pistol shooting performance compared with placebo. Shooting improved by 13.4% of possible improvement (i.e., 600 points minus actual points obtained) as an average (SE = 4%, $2P < 0.002$). The most skilled athletes demonstrated the clearest metoprolol improvement. We found no correlation between the shooting improvement and changes in the cardiovascular variables (i.e., changes of heart rate and systolic blood pressure) and no correlation to the estimated maximum O_2 uptake. The shooting improvement is an effect of metoprolol on hand tremor. Emotional increase of heart rate and systolic blood pressure seem to be a β_1-receptor phenomenon.

beta-adrenergic receptor blocking agents; exercise; exertion; sports medicine; doping in sports; tremor; tachycardia; hypertension; anxiety

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BETA-ADRENERGIC RECEPTOR BLOCKERS (BB) are used by ballet dancers, musicians, archers, marksmen, ski jumpers, and many other artists and athletes (2, 4, 14). The use of drugs in an attempt to improve athletic performance is rarely based on facts about the effect of the drug. Ignorance, credulity, and perhaps psychological pressure from the surroundings seem to rush, in particular, young athletes into doping situations. The Medical Commission of the International Olympic Committee lists the doping agents, and to this list BB has been added by the Commonwealth Games Association (13). However, the effect of BB on the central nervous system is controversial (12). BB also have anxiolytic effects (5) and reduce different types of tremor (7). These effects may be peripheral or central and imply alterations of human performance in situations of nervous stress.

We have chosen the β_1-receptor blocker, metoprolol, which is structurally related to isoproterenol (a potent β-adrenergic agonist), as are almost all BB. Orally administered metoprolol has been chosen because it is easily absorbed from the gastrointestinal tract. With a maximum heart rate and blood pressure reduction between 1 and 3 h, 12% is bound to plasma proteins and the mean half-life is 3 h (10). Metoprolol acts by competition with catecholamines at the β_1-receptors, thereby blocking the chronotropic effect on the heart (i.e., reduction of the cardiac output mainly by lowering the frequency). Metoprolol, as does training, also reduces O_2 consumption and increases the arteriovenous O_2 content difference during exercise (15). The training condition was estimated as maximum O_2 capacity. We hypothesized that BB did not change the performance of pistol marksmen (i.e., the zero hypothesis). The object of the present report was to test the null hypothesis.

METHODS

We studied 33 amateur marksmen who used a standard pistol at a distance of 25 m. There were 2 women and 31 men aged 20–60 (median 40) yr. All subjects had a medical examination, including electrocardiogram and measure of estimated maximum O_2 uptake after the method of Åstrand and Rodahl (1). Data are presented in Table 1. Anybody with pulmonary or cardiovascular disorders, including coronary infarction and hypertension, or receiving medical treatment was excluded from the study. All volunteers accepted were members of the same association. The study was approved by the local ethical committee, and informed consent was obtained from all.

A double-blind crossover trial was designed. Two competitions were arranged for all participants with a 1-wk interval. Rewards were offered for the best shooting. Metoprolol and identically looking tablets of placebo (calcium lactate) were dispensed according to a computer-controlled selection plan. Seventeen marksmen received metoprolol at the first competition and 16 at the second. The dosage of metoprolol was 50 mg in the morning and 100 mg 2 h before shooting. All subjects responded with a fall in heart rate and/or in systolic blood pressure. Heart rate and arterial blood pressure were measured immediately before and following shooting.

Each competition was carried out in three separate periods (*I, II,* and *III*) consisting of four series, with five shots at each series. The duration of each series was 150, 20, and 10 s in *periods I, II,* and *III*, respectively. Each competition thus consisted of three periods times four series time five shots, each rewarded with a theoretical

TABLE 1. *Anthropometric medians for 33 marksmen*

	Median	Range
Age, yr	40	60–20
Ht, m	1.77	1.88–1.56
Wt, kg	81	121-59
Resting heart rate, beats/min	72	84-52
Systolic blood pressure, mmHg	130	160–110
Diastolic blood pressure, mmHg	80	95–60
Maximum O_2 uptake, ml STPD $\cdot$ $min^{-1} \cdot kg^{-1}$	36	67–19

maximum of 10 points (bull's-eye on target). Thus the maximum score was 600 points.

The conditions of the two competitions were the same regarding weather, emotional alertness, and practical arrangements. The sums of all points obtained at the two competitions by all participants were 16,523 and 16,718 points, respectively. The difference between the maximum 600 points obtainable and the actual points obtained was calculated and used in the following placebo-to-metoprolol "shooting ratio": (600 − placebo points)/(600 − metoprolol points). A ratio of 1.0 confirms the zero hypothesis, <1.0 implies that metoprolol worsens the shooting performance more than the placebo, and ratios significantly >1.0 show that metoprolol ameliorates shooting performance compared with placebo. Poor shooters are not the best to use in studies of improvements among elite athletes. The results obtained by poor shooters must be expected to function as "noise" in relation to the best national marksmen studied here. The above defined shooting ratio does not weigh the skilled marksmen more than the poor shooters, but the shooting ratio prevents an individual improvement from being hidden. Mean and median values are more dependent on the relative number of poor and skilled marksmen than on their actual performance.

The shooting ratio is simply a digital expression of the direct and intelligible information obtained at a glance on the shooting results in Fig. 1. The shooting ratio is the tangent of the angle in the third quadrant of the coordinate system in Fig. 1, between the x-axis and lines through each point and the origin (600,600). Shooting results located at the line of identity (i.e., shooting ratio of 1.00) confirm the null (zero) hypothesis (Fig. 1).

Text, graphics, and data handling were peformed with a Sperry Univac 1100/82 computer. The level of significance was chosen as two-sided $\alpha = 0.05$.

RESULTS

We compared three variables (shooting points, heart rate, and systolic blood pressure following shooting) from the metoprolol-enhanced and placebo shooting. The variables are plotted with metoprolol results as abscissa and placebo results as ordinate (Figs. 1–3). Each cross corresponds to the data for an individual at the two shootings. Crosses located above the line of identity show higher absolute values on the placebo shooting than on the metoprolol shooting and conversely crosses located below the line show higher metoprolol values (Figs. 1–3). Twenty-two marksmen (below the line of identity) had better results on metoprolol than on placebo.

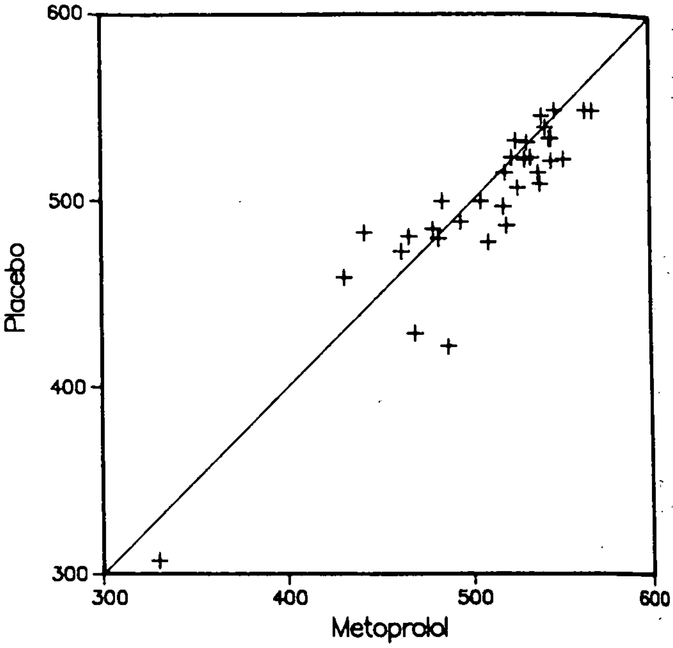

FIG. 1. Plot of metoprolol vs. placebo shooting points. Line of identity is drawn solid to a theoretical maximum (600,600).

Metoprolol obviously improves shooting performance (Fig. 1). Almost all participants were skilled pistol marksmen with scores above 500 points. The skilled shooters had crosses below the line of identity, each point indicating the results of the marksmen at the two competitions (Fig. 1). A few poor shooters spread around the line (Fig. 1). The distribution of all 33 shooting ratios (0.74–1.58) was, with good approximation, shown to be normal. A placebo-to-metoprolol shooting ratio of 1 appears on the line of identity in Fig. 1. A ratio significantly >1 indicates improvement of shooting results as a result of metoprolol. We tested the zero hypothesis by a Student t test. The average placebo-to-metoprolol shooting ratio was 1.134 (SE = 0.040; n = 33). The hypothesis was rejected ($2P < 0.002$). Metoprolol significantly improves the shooting.

The median heart rate before and after shooting was 76 and 72 beats/min with placebo and constant at 60 beats/min with metoprolol (Table 2). The median values for systolic and diastolic blood pressure were also 5–10 mmHg less before and after shooting with metoprolol than with placebo (Table 2), but median (and mean) values can be poor indicators. The mean values of the placebo group (Table 2) are significantly different from the metoprolol group ($2P < 0.001$), except for the diastolic blood pressure.

Plots of paired values following the two shooting competitions showed obvious reduction of heart rate (Fig. 2) and systolic blood pressure (Fig. 3) during influence of metoprolol with most points above the line of identity. Many marksmen had emotional tachycardia or hypertension on placebo before and also just after the competition (Figs. 2 and 3). The remaining marksmen, with higher maximum O_2 capacity and lower resting heart rates, had only a tonic adrenergic increase in heart rate and systolic

TABLE 2. *Different variables for 33 marksmen*

	Heart Rate, beats/min	Systolic Blood Pressure, mmHg	Diastolic Blood Pressure, mmHg
Before Shooting			
Placebo			
Mean ± SE	75±2.2	142±2.6	87±1.5
Median	76	140	90
Range	48–104	115–170	65–110
Metoprolol			
Mean ± SE	59±1.9	132±2.6	85±1.6
Median	60	140	85
Range	40–64	110–160	70–105
After Shooting			
Placebo			
Mean ± SE	73±2.9	141±2.7	89±1.5
Median	72	135	90
Range	48–100	115–175	70–110
Metoprolol			
Mean ± SE	60±1.4	131±2.7	87±1.9
Median	60	130	85
Range	44–72	110–170	70–110

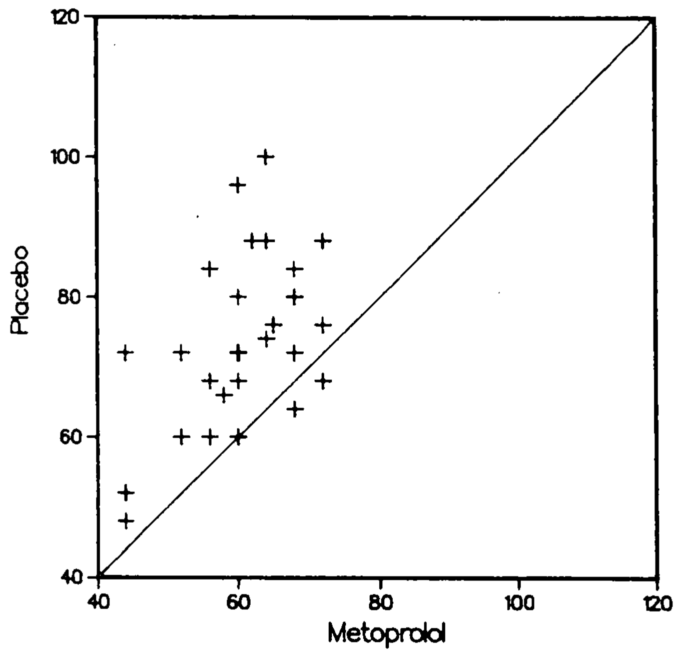

FIG. 2. Plot of heart rate following shooting; metoprolol vs. placebo.

blood pressure just before the competition on placebo. The correlation coefficient between the placebo-to-metoprolol shooting ratio and the placebo-to-metoprolol heart rate difference (i.e., the difference in placebo and metoprolol heart rate) following shooting was −0.237 and for the placebo-to-metoprolol systolic blood pressure difference following shooting: 0.131. None of these coefficients are significantly different from zero.

DISCUSSION

Metoprolol evidently improves shooting performance compared with placebo. The improved shooting performance must either be due to the changes of cardiovascular variables (i.e., changes in heart rate or in arterial blood

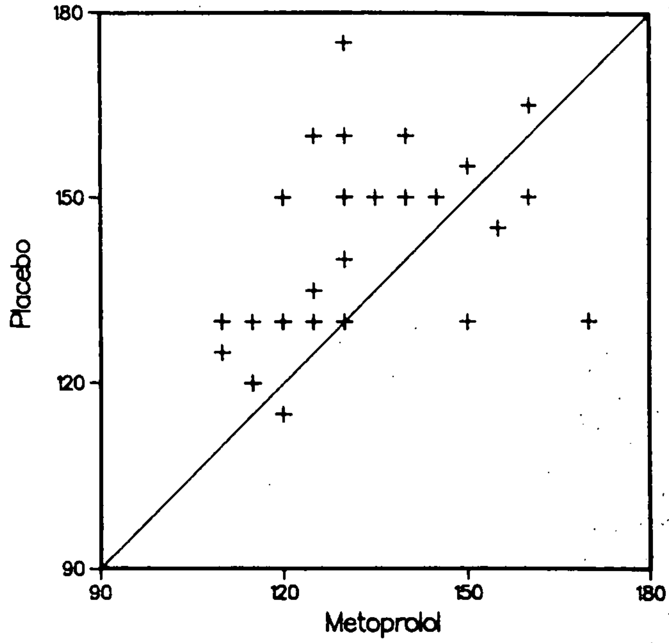

FIG. 3. Plot of systolic blood pressure following shooting: metoprolol vs. placebo.

pressure) or to other factors. We found no statistically significant correlation to the cardiovascular alterations measured here or to the maximum O_2 uptake estimated. Thus the improved shooting performance (measured as a shooting ratio >1 or location below the line of identity in Fig. 1) is probably not due to the recorded changes in cardiovascular variables and possibly not either to the passive vibrations produced by the activity of the heart.

Thus other factors must be considered, and the physiological neural hand tremor is a likely candidate. In pistol marksmen such a hand tremor may even be estimated accurately by the shooting results obtained. If the hand tremor is of neural origin, then it is an open question whether improvement with metoprolol is a central or a peripheral effect.

Metoprolol and propranolol are successful in the treatment of essential tremor, and since they readily cross the blood-brain barrier, the successful treatment is often considered to be caused by a central effect (6, 16, 18). But other scientists consider peripheral rather than central BB responsible for the effect on hand tremor and on "somatic" anxiety states, either mediated by an effect on peripheral β_1 or β_2-adrenoceptors (3, 9, 17). BB seems to have a low frequency of central effects in humans, and metoprolol is almost free of unwanted central effects in our healthy subjects. Injection of catecholamines in the brachial artery of man strongly increases physiological hand tremor, and the tremor increase can be abolished by DL-propranolol (11). This can be demonstrated unilaterally by arterial occlusion to one limb or by injection of DL-propranolol into one brachial artery (11). Peripheral nervous or hormonal blockade is thus a possible mechanism for the metoprolol effect on pistol shooting performance (i.e., physiological hand tremor), but the data generated do not allow any conclusion.

Our pistol marksmen rested in the standing position before, during, and after the shooting, so the small rise in heart rate just before the shooting must be purely emotional. Tachycardia due to emotional stress is predominantly mediated by β-adrenergic receptors (8). In our study a high heart rate, due to emotional alertness, was reduced to a median heart rate of 60 beats/min by metoprolol, so we can confirm the results of Imhof et al. (8), and emotional tachycardia seems to be mediated by β_1-receptors; just as tonic adrenergic increases of heart rate and of systolic blood pressure. The literature does not contain any comparable study of the effects of β-blockers on shooting performance. The literature does not either contain any basis for the assumption that β-adrenergic receptor blockers reduce intellectual performance. Thus the prescription of BB to apparently healthy persons on indications as tremor, anxiety, and tachycardia is understandable, but not totally devoid of danger. Prescription must always be preceded by exclusion of asthma, atrioventricular block, and cardiac insufficiency. The consequences for precision sports are that the use of β-adrenergic blockers must be either banned or legalized for all. These drugs are banned as doping in precision sports, so persons in hypertensive treatment can only participate in shooting competitions with special permission.

In conclusion, metoprolol improves pistol shooting performance compared with placebo. The improvement is probably due to a nervous effect on hand tremor, dominated by a β_1-receptor blockade. Emotional increases in heart rate and systolic blood pressure are eliminated by metoprolol and may thus be a β_1-receptor phenomenon.

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