Electromyographic activity of the M. biceps brachii in various shooting positions in the standing position in biathlon shooting

Dirk Siebert[1], Engelbert Sklortz[2], Nico Espig[1]

Institute of Movement and Training Science in Sports II, Department: Winter Sports/Faculty of Sport Science, University of Leipzig[1], ([1]Head: Jun.-Prof. Dirk Siebert, Ph.D., [2]Federal Police Sports School Bad Endorf)

Summary

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Objective
The importance of shooting performance in biathlon is continuously increasing. A strong performance in precision tasks is necessary for high shooting results. Therefore the shooting position has to ensure a stable foundation of athlete and rifle. It remains unanswered how different shooting positions affect the muscular activity of musculature responsible for fixation of the weapon during shooting. The aim of this study was to make a contribution in forming a valid tension profile of musculature involved in standing shooting position in biathlon.

Material and methods
The research of the present study was carried out on seven athletes of the German Junior-National Team. Every subject had to complete three shooting series in a 15 s interval in standing position with three different positions of the butt plate. During the shooting series the angle of the shoulder axis, as well as the electromyographic activity of the M. biceps brachii were quantified.

Results
1. Muscular activity is significantly dependent on shooting position.
2. Variations of the butt plate configuration lead to a significant change in the angle of the shoulder axis.
3. In relation to the original shooting position, muscular activity in shooting with the largest angle of the shoulder axis increased by 85 %.
4. The research results show the lowest activity level of the M. biceps brachii for the original shooting position.

Conclusions
The study could clearly demonstrate the influence of various shooting positions on the muscular activity and, therewith, the importance of a tension-free and stable shooting position could be emphasized.

Keywords: biathlon, shooting, EMG, goniometry

Introduction

Over the last few years, biathlon has developed into one of the most well-covered winter sports by the media. Some responsible factors for this have been the changes in its competition systems. The introduction of new competition disciplines have ensured that an increasing number of competitions must be completed in both relay-start as well as mass-start situations. As a result, running against the clock in competitions has faded into the background. Further, these changes led to proportionally more bouts of shooting compared to skiing. There through, shooting performance, in comparison to the complex performance in the context of biathlon, is gaining more and more importance. In the future, a competitor must achieve a shot accuracy of 90-95% within an appropriate shooting time in order to be considered for a medal (7). The accuracy of the shot depends significantly on the appropriate form of the most important technical shooting elements. Examples of general technical shooting elements are: breathing, triggering, targeting, and stance, as well as their optimal coordination (5). The shooting stance has the function of ensuring a stable position of the system athlete/weapon and, therewith, the smallest possible degree of fluctuation of the muzzle at the moment of trigger release, even with quick shooting rhythms (2). In order to ensure a successful hit, the movements of the muzzle at the moment of trigger release must be less than 0.4 mm when shooting in prone position, or 1.0 mm when shooting in standing position (1). Therewith, changes in the shooting position at the moment of trigger release in particular lead to greater movements of the muzzle. These changes of the stance are made up of variations of the entire system: sway between the ball of the foot and the heel or between the left or right leg, the angle change of the body parts which are involved in the stance (6), the muscular tension of the supporting muscles affected by the stance (2), and the generation of tremor as a result of carrying the weapon for longer while in the stance (3, 4). The high run load which happens before the rounds of shooting leads to an increasing ergotropic functioning, mostly through the activation of the sympathoadrenal system. This state reinforces negative effects of the contributing muscles in the firing position. However, in an appropriate shooting position, this influence is reduced to a minimum as a result of optimal positioning of different body parts — primarily ligaments, tendons, and bones — and without much muscular involvement (2). In a previous EMG study, it was found that athletes do not always take the position of least tension and, therefore, the muscular tension has a negative effect on the muzzle movements (7).

In order to achieve the most stable position of the athlete and weapon, it is necessary, due to the recoil energy after shooting, to develop an optimum between the smallest amount of muscular tension of the involved postural muscles and a necessary amount of tension of the muscles responsible for the fixation of the weapon. Thus, during shooting executed, e.g., on the right side of the body, it is the responsibility of the right M. biceps brachii to ensure a stable power triangle between the handle piece, right elbow, and butt plate. There through, the pressure on the butt plate is raised and the possible range of movement of the weapon is significantly reduced after the release of the shot.

The objective of the present study was to find out how various shooting positions affect the activity of the muscles which involved in biathlon shooting. In preliminary studies, it was shown that the postural muscles are significantly dependent on the shooting position and can be affected positively through optimal variations in form. It remains unanswered how these shooting positions affect the muscles responsible for the fixation of the weapon and whether it is necessary based on these realizations to change the shooting stance accordingly. In the framework of this study, the right M. biceps brachii was exemplarily researched. Therewith, the neuromuscular activity level of the right M. biceps brachii was identified for three different shoulder-axis angles using EMG in a standing shooting position. The purpose is to use this information to devise which angle of the shoulder axis — relating to the most tension-free yet also stable stance — can be determined to be most recommendable for standing shooting.

Methods

The research of the present study was carried out on seven athletes of the German Junior-National Team (2 w/ 5 m, ages: 20.5 ± 1.4 years) within the context of a shooting course of the German Ski Association at the Olympic shooting range in Garching-Hochbrück. Three different standing shooting stances were carried out by the participants using their own weapons; each shooting session was 15 seconds long and included five shots. The three different shooting stances were realized with a height adjustment of the butt plate (BP) at the end of the weapon. The height adjustment of the butt plate led to a changed angle of the shoulder axis (∢WSA). All other individual weapon adjustments remained the same. Position one (BP ± 0 cm) is the unchanged weapon setting and, therewith, the usual position of the shoulder axis of each participant. Position two was reached through a height change of + 3 cm of the butt plate (BP + 3 cm) and, consequently, a wider angle of the shoulder axis in relation to the shot level/height. At position three (BP - 3 cm), the butt plate was fixed 3 cm below the first position. The data acquisition of the shooting position and angle was completed using the movement analysis software Dartfish ProSuite (Taufkirchen, Germany) from the frontal plane and was related to the fulcrum of the left and right shoulder joint (shoulder axis) as well as the lengthening of the gun barrel. The neuromuscular activity level of the posterior muscles activated during the shooting stance was carried out using the example of M. biceps brachii by employing EMG analysis. Additionally, based on the approved standards of the SENIAM group (www.seniam.org), the EMG signals were recorded during the 15 seconds by the attached hardware and software (Noraxon, Cologne) with a sampling frequency of 1000 Hz. Finally, the raw data were smoothed out by using moving average.

Results

Angle of the Shoulder Axis (∢WSA)

The determination of the shooting stance in standing position was carried out in means of determining the angle of the shoulder axis (∢WSA) in relation to the shot level/height (the lengthening of the gun barrel). In Table 1 the angles of the shoulder axis are shown for each participant measured in dependence of the three different positions of the butt plate. It is clearly visible that the participants show a considerable variety in the way they are working out their original shooting stance (BP ± 0 cm). Thereby, the range is 11.2 °. Furthermore it is obvious, how the height changes of the butt plate influence the angle of the shoulder axis. In relation to the original shooting position of the participant, a height change of + 3 cm of the butt plate (BP + 3 cm) leads to an increase of the angle of the shoulder axis by 5.8 ° (62 % respectively). By analogy, a height change of -

3 cm of the butt plate (BP - 3 cm) leads to a reduction of the angle of the shoulder axis by 4.1 ° (44 % respectively). In both cases, changes of the angle of the shoulder axis (∡WSA) have shown to be statistically significant (P < 0.05).

Table 1. Angle of the shoulder axis (∡WSA. in °) depending on the position of the butt plate

Participant nr.	BP ± 0 cm	BP + 3 cm	BP - 3 cm
1	6.6	10.2	2.8
2	5.0	9.6	1.3
3	9.9	16.7	7.1
4	6.9	17.2	5.8
5	12.4	18.1	8.5
6	16.2	20.3	4.9
7	8.8	14.6	6.6
AM / SD	9.4 / 3.6	15.2 / 3.7	5.3 / 2.3

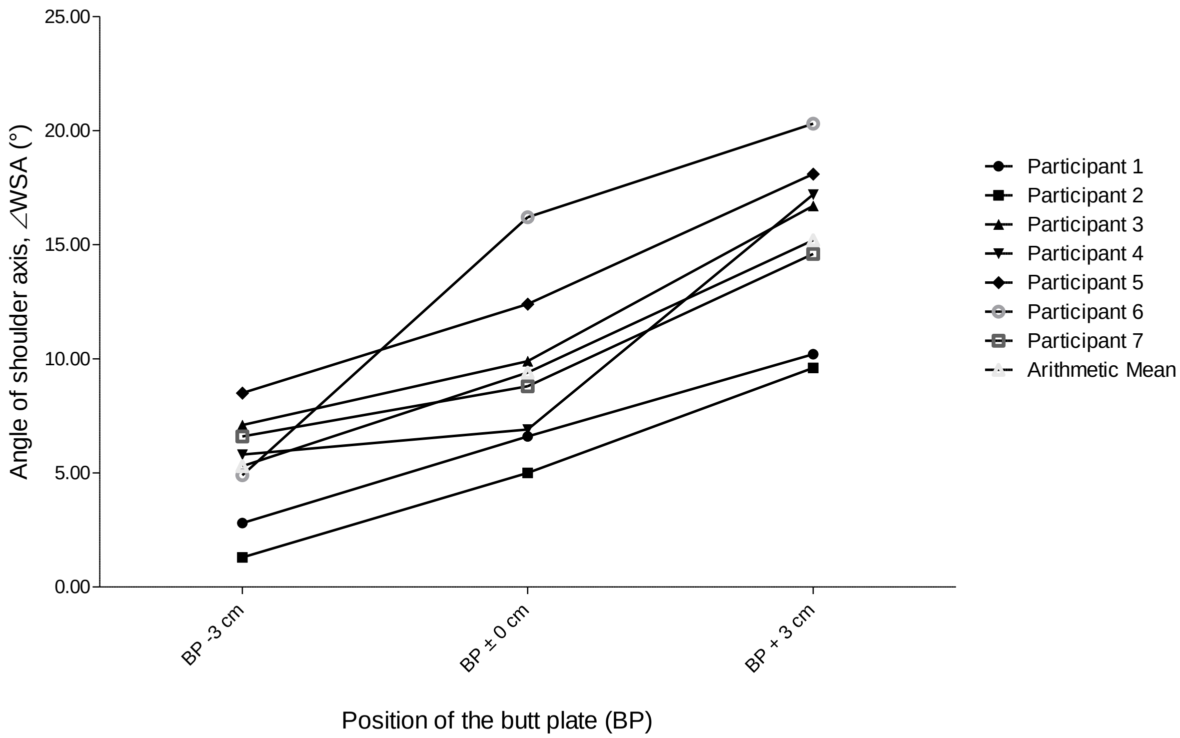

Figure 1. Angle of the shoulder axis (∡WSA, in °) depending on the position of the butt plate

Activity level of M. biceps brachii

The compilation of neuromuscular activity of the M. biceps brachii was completed for every participant for the three various shooting stances. In Figure 2, for example, the activity level of a participant is represented during the course of 15 seconds. In Table 2, individual activity levels of the various participants are represented. Beginning with the normal position of the participant, there was then a shift of the butt plate by 3 cm upwards (BP + 3 cm) to an average rise of the activity level of M. biceps brachii by 85 %. With a shift of the butt plate to 3 cm below the beginning position (BP - 3 cm), there was an average rise of the activity level of M. biceps brachii by 31 %.

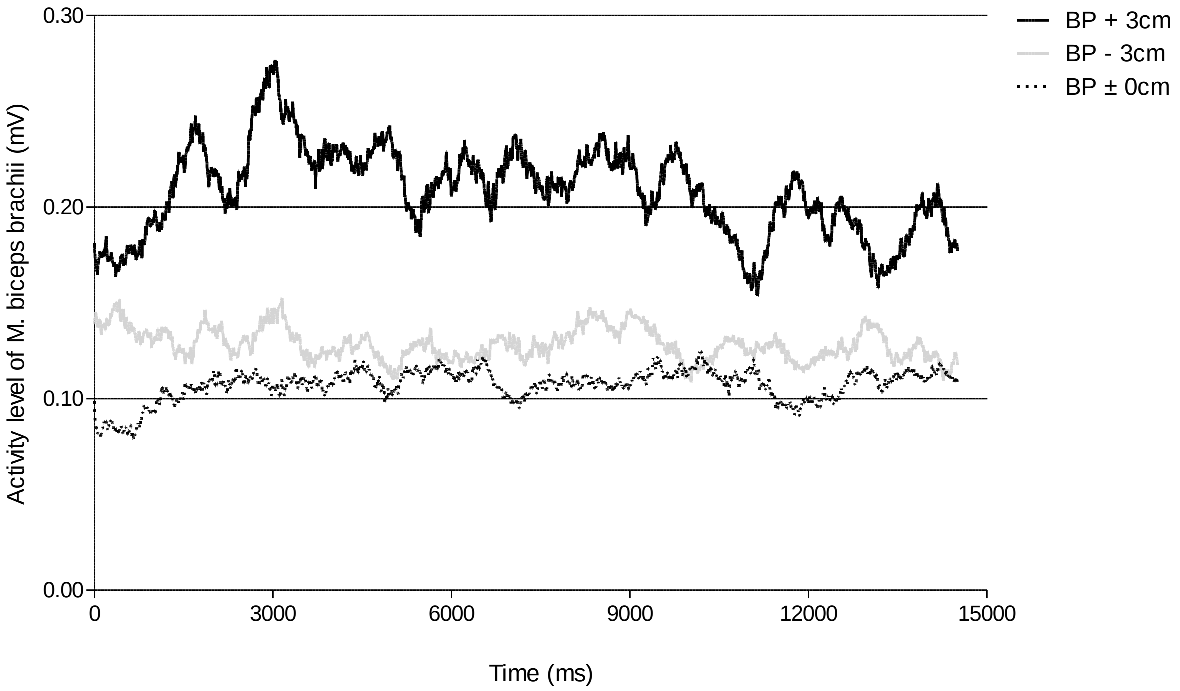

Figure 2. Activity level of M. biceps brachii in dependence on three different shooting positions, e.g. for a participant

Table 2. Activity level of M. biceps brachii in dependence on the position of the butt plat

Participant nr.	BP ± 0 cm	BP + 3 cm	BP -3 cm
1	0.0595	0.0984	0.0636
2	0.0420	0.2619	0.2160
3	0.1167	0.1615	0.1411
4	0.1073	0.2086	0.1284
5	0.1304	0.2136	0.1116
6	0.0839	0.0962	0.0674
7	0.0769	0.0977	0.0786
AM	0.0881	0.1626	0.1152

Comparative observations of EMG and angle analysis

Represented parallel to one another in Figure 3 are the changes of the angle of the shoulder axis (∡WSA) and the changes of the activity level of M. biceps brachii in dependence on the various positions of the butt plate. It becomes obvious how directly the changes of the shooting stance affect the activity level of the involved posterior muscles. Through using the T- Test, significant differences of the angle of the shoulder axis between the various shooting positions could be determined ($P < 0.05$). In relation to the activity level of the M. biceps brachii, some significant differences between the positions of “BP ± 0 cm” and “BP + 3 cm” ($P < 0.05$) as well as between the positions “BP + 3 cm” and “BP - 3 cm” ($P < 0.01$) are provable. Between the normal position of the participants (BP ± 0 cm) and the position with a lowered butt plate (BP - 3 cm), no significant statistical differences were found.

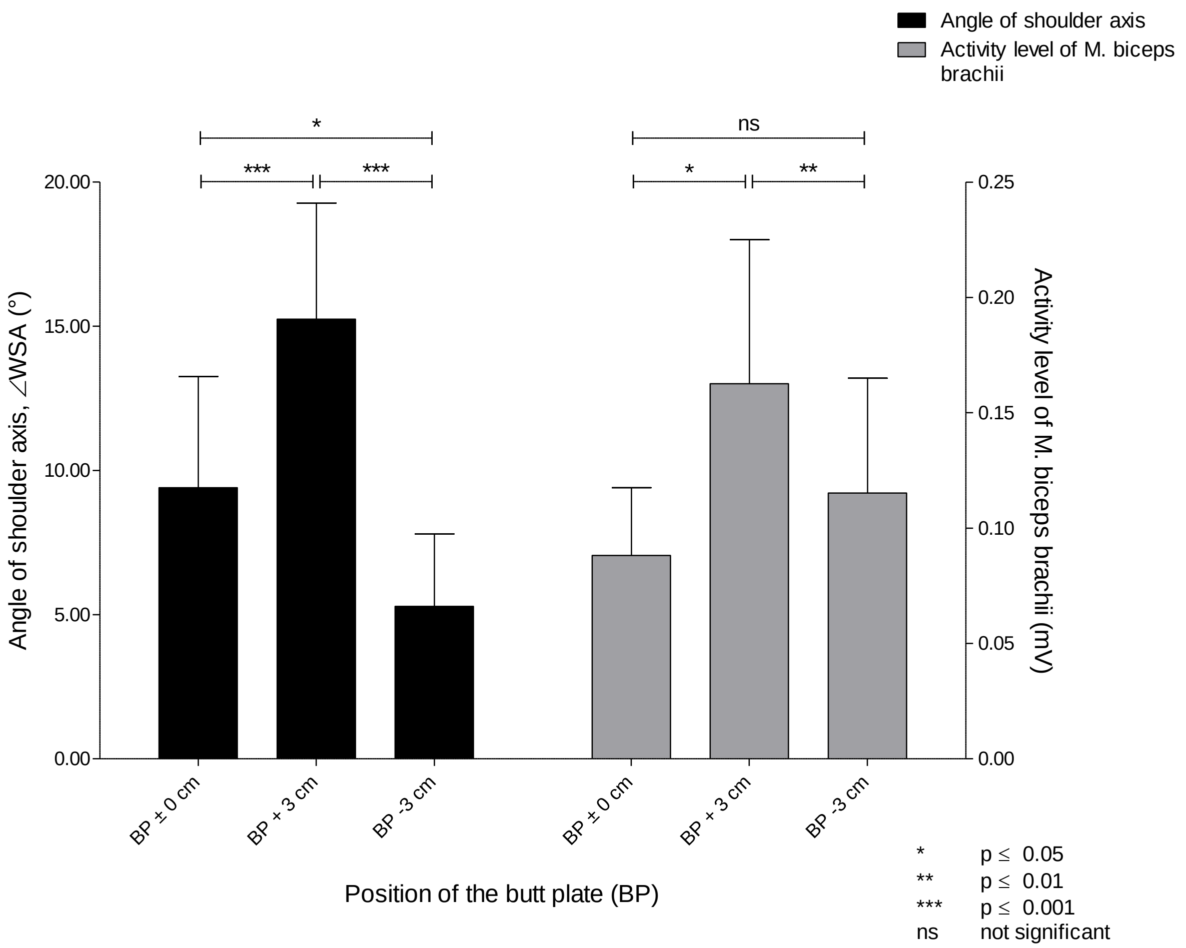

Figure 3. Angle of the shoulder axis and activity level of the M. biceps brachii at various standing shooting positions in biathlon

Discussion

In attempt to achieve the most tension-free but also stable upright stance during biathlon shooting, the influence of various shooting positions on the neuromuscular activity of the involved musculature was studied. The studied activity level of the M. biceps brachii exhibits in part a significant dependence on the angle of the shoulder axis. A larger angle of the shoulder axis, in comparison to the original shooting position of the athlete, raises the activity level of the right M. biceps brachii. Thereby, the highest activity level was measured in the position of BP + 3 cm (i.e. the butt plate was shifted upwards 3 cm). With smaller angles of the shoulder axis, significantly lower tension was measured in this muscle. Thereby, however, the tension in the original shooting position of each athlete was especially low. In this regular position, the minimum of the measured muscular activity of the M. biceps brachii was established. The study results, thus, only partially indicate appropriate and inappropriate variants of form for standing shooting positions.

A differing view to be considered is, first, the monocausal requirement for the least tension possible of the musculature which is involved in the shooting stance in order to raise shooting stability. It is additionally necessary to divide the roles of the muscles involved in the stance into passive and active parts. The function of the passive supporting muscles in the stance is to create the least amount of tension and to support the weight of the athlete and weapon through skilful positioning of the body parts, over ligaments, tendons and bones (2). It is the function of the active part of the musculature to fix the weapon so that the recoil energy is absorbed as much as possible and the muzzle of the weapon after trigger release changes position as little as possible. The M. biceps brachii, in addition to the M. flexor digitorum superficialis, ensures a fixing of the weapon through a power triangle between the handle piece, right elbow, and butt plate. In this study, various angles were provoked through a change in the height of the butt plate. As a result, different applied forces of the fixing work of the M. biceps brachii subsequently followed. The role of the active musculature in the shooting stance can be described in the following way: as much energy as necessary and as little energy as possible must be exerted. As a result of this, a large shoulder axis angle, in comparison to the original shooting position, is regarded as an unfavourable position for M. biceps brachii because of the high muscular activity level. This assertion is, however, only sufficiently applicable for the case when it is clear which muzzle movements and which forces on the butt plate are affecting during the various shooting positions. At the moment, it cannot be proven that the high activity level of the M. biceps brachii does not perhaps come from the fact that much higher force reaches the butt plate and, thus, perhaps this results in lower muzzle variations. This ambiguity must be cleared up in future studies.

The research results show the lowest activity level of the M. biceps brachii for the original shooting position (BP ± 0 cm). On the grounds of these realizations, it can be assumed that, over the course of multi-year processes of technique learning, an individual optimum already developed for the lowest tension possible in the postural musculature and the highest tension possible in the musculature responsible for fixation of the weapon during shooting stance. As a result of this, it is necessary to simultaneously record or evaluate the muscular activity level with the forces exerted on the butt plate, as well as the movements of the muzzle, in order to deduce positive and negative forms of the shooting position.

In this study, M. biceps brachii was exemplarily considered. To achieve detailed and comprehensive figures of the stance-specific muscular activity-patterns, it is necessary to bring more of the involved muscles into focus. Thereby, it is essential to test to what extent the underlined shooting positions in this study would affect the activity level of the other muscles. Related to this, it can be assumed that changes of the shooting positions affect the activity of the various muscles at different levels, and an optimal as well as tension-free shooting position under these conditions must be newly evaluated.

In light of the aforementioned statements, it is also necessary to test whether, in addition to the position, the size of the involved muscles has a definitive role in the observation of the tension-profile.

Starting with the same target height, athletes with various extremity lengths and body size are forced to individually adapt to a shooting position. The shooting position is, therefore, significantly dependent on body size (6). To form a valid tension-profile of the musculature in standing shooting stances, it is therefore necessary to take into account individual anthropometric differences and their influence on the shooting stance.

Since the shooting technique in biathlon is considered as a complex structure, analysis of shooting stance and various positions must always be considered in connection with the other numerous partial elements of the shooting technique as well as the internal and external influencing factors on the shooting results. It is only in this way that universal statements and deductions can be attained for training praxis. The study could, however, clearly demonstrate the influence of various shooting positions on the muscular activity and, therewith, the importance of a tension-free and stable shooting position could be emphasized.

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Contact: Jun.-Prof. Dirk Siebert, Ph.D.
University of Leipzig
Faculty of Sport Science
Institute of Movement and Training Science in Sports II, Department: Winter Sports
Jahnallee 59
D-04109 Leipzig
E-Mail: dirk.siebert@uni-leipzig.de Fax: +49341-9731737 Tel.: +49341-9731727