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Stability analysis of motion patterns in biathlon shooting

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ABSTRACT

The aim of this study was to analyze the stability of the aiming process of elite biathlon athletes. Nine elite athletes performed four series of five shots onto the same target and onto targets next to each other in a shooting hall. A video-based system reconstructed the horizontal and vertical motion of the muzzle. The time period starting after repeating the rifle and ending with the shot was divided in 10 intervals of equal duration. Eight kinematic parameters describing the motion in these intervals were calculated. Based on the parameter values obtained a special variant of an artificial network of type SOM (self-organizing map) was trained. Similar neurons were combined to clusters. For each shot the 10 data sets describing the aiming process were then mapped to the corresponding neurons. The sequence of the related clusters in the respective succession was used as representation of the complex aiming motion. In a second processing step types of shots were identified applying a second net. A more stable pattern could be inferred for the members of the national squad compared to the biathletes classified in the next best performance level. Only small differences between the two shooting conditions could be observed.

1. Introduction

Biathlon is a Nordic sport that combines the intense physical demands of cross-country skiing with the precision of rifle marksmanship (Groslambert, Candau, Hoffman, Bardy, & Rouillon, 1999; Hoffman, Gilson, Westenburg, & Spencer, 1992). The aiming process in biathlon shooting is a crucial

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factor for success. Athletes have to perform a series of shots onto five targets next to each other 50 m away. A well controlled motion of the barrel just before shooting is essential. This is even more difficult to achieve after a preceding load due to cross-country skiing. Shooting performance obviously depends on the intensity of this load (Grebot & Groslambert, 2003; Vickers & Williams, 2007). This is particularly the case for shooting in the standing position because stability of hold is more affected (Hoffman et al., 1992). In addition to the intensity of the preceding load there are several other factors affecting the aiming process: weather conditions (e.g., light, wind), equipment, and physical condition.

It has been reported that shooters and biathletes apply different shooting strategies (Larue, Bard, Otis, & Fleury, 1989; cited in Groslambert et al., 1999). While shooters attempt to control body and rifle fluctuations, biathletes use coincidence-anticipation strategies. They try to align aiming line – target as soon as possible and shoot immediately after the first stable alignment (Nitzsche, 1998). The mean duration from the appearance of the target in the rifle ring to shooting is reported as being only some 100 ms (Nitzsche, 1998).

It may be assumed that elite biathletes show a very stable aiming pattern and that this stability is highest for the best performance class. However, aiming patterns are difficult to assess because of their high complexity.

Exemplary patterns are illustrated in Fig. 1. A commercial laser-based system (Noptel-ST-2000, Noptel OY, Oulu, Finland) has been used to obtain the on-target-trajectory depicted left, a video-based system (Baca & Kornfeind, 2006; Heller, Baca, Kornfeind, & Baron, 2006; see Section 2 for details) for reconstructing the 2D-motion (up/down, left/right) of the muzzle depicted right. The main advantage of the laser-based method is that it is directly related to the shooting result, although there may be some fluctuation of the on-line-trajectory with regard to the aiming line due to turning the weapon around the axis of the barrel (i.e., the aiming line). One essential advantage of the video-based method is that no sensors or devices have to be attached to the rifle or the athlete, what is of great importance for applications in practice (Nitzsche & Koch, 2000). It should, however, be noted that three kinds of rifle movements which are most influential in shooting results have to be distinguished (Zatsiorsky & Aktov, 1990): Angular movement relative to the butt rest point against the shoulder in the vertical plane and translation as well as angular movement in the horizontal plane. Particularly there is no way to identify any compensation for each other in the horizontal plane using either the laser-based system or the video-based method alone.

The application of artificial neural networks has proven to be helpful for identifying patterns and process types when investigating such complex motor tasks or processes (e.g., Memmert & Perl, 2009a, 2009b; Pfeiffer & Perl, 2006). Neural networks of type SOM enable to map the complex motion process to a two-dimensional trajectory described by a sequence of neurons, where each neuron represents a unique state of this process. The special variant of a SOM-type network as proposed by Perl

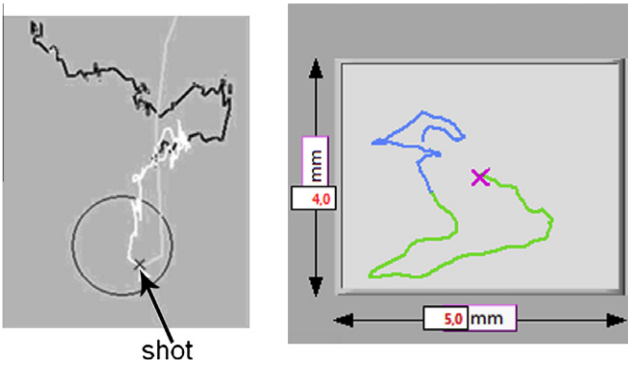

Fig. 1. Examples of on-target- and muzzle-trajectory. Left: On-target-trajectory obtained by Noptel-ST-2000 shown 3 s prior to the shot up to the shot (white marked: 1 s prior to the shot up to the shot). Right: Muzzle-trajectory obtained by video based system (see text for details) 3.48 s prior to the shot up to the shot.