Original Article

Dynamic rifle stability is not influenced by exercise intensity in young biathletes

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ABSTRACT

The aim of the study was to analyse and find out potential dependence between the dynamic rifle stability during targeting and percentage pressure value on the trigger 1 second and 0.5 second before the shot in different intensities of the physical load. Fifteen national youth and junior elite biathletes (ten women, five men) from a team of the Czech Republic participated in the study. All participants completed measuring of the dynamic behavior of the rifle in rest and after roller skiing in three different exercise intensities: Intensity 1 = 70 % of HR_{max} (maximum heart rate), average speed 4.1 – 4.6 $m \cdot s^{-1}$; Intensity 2 = 80 % of $HR_{max,}$ average speed 4.5 – 5.0 $m \cdot s^{-1}$; Intensity 3 = 90 % of HR_{max}, average speed 4.9 – 5.4 $m \cdot s^{-1}$. Each bout consisted from a distance of one km. They shot in standing position with using their own biathlons rifle with a fixed accelerometer and trigger sensor. The data used in our research showed that the dynamic rifle stability is not influenced by exercise intensity neither in the men nor women group. However, our study demonstrated that the rifle stability is better in time 0.5 second before the shot than in time 1 second before the shot. The measurement of triggering in our study showed that participants are able to work with their fingers on the triggers in similar quality in the racing load as well as without the previous physical load.
Keywords: Biathlon training; Shooting analysis; Physical load.

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INTRODUCTION

The biathlon is a winter sport that combines two very different disciplines, namely cross-country skiing and long rifle shooting. It has become one of the most popular and most watched sports in the Czech Republic during recent years. The clear goal of the Czech biathlon union, an umbrella organization of this sport in Czechia, is to build on the success of the current generation and to raise new talents like Gabriela Koukalová, Veronika Vítková, Michal Krčmář or Ondřej Moravec. The basic assumption of this goal is a long-term systematic training led by experienced trainers. Trainers should have years of practice in a conditioning training, methodology of shooting training and other components necessary for training of biathletes. This study has been focused on an assessment of factors influencing the shooting success during trainings and competitions of youth and junior categories in biathlon. The aim of the study was to analyse and ascertain potential dependence between the dynamic rifle stability during targeting and percentage pressure value on the trigger 1 second and 0.5 second before the shot in different intensities of the physical load. Observed parameters were measured only in standing shooting position.

Biathlon shooting performance is influenced by many various factors. Žák et al. (2016) divided factors contributing to the final shooting results according to their character into two basic groups. In the first group there are psychosomatic factors (endogenous; such as shooting technique, physical fitness and psychic maturity of the athlete and his psychomotorics) and in the second one so called technical factors (exogenous; such as material and technical equipment of the athlete, sports-technical conditions of the biathlon stadium and climate conditions).

The majority of researches that have been presented so far were chiefly focused on the stability of the standing shooting position, the stability of the rifle during targeting, triggering and the dependence of the above mentioned parameters on the shooting success (Gallicchio et al., 2018; Haug, 2018; Ihalainen et al., 2018; Laaksonen et al., 2018; Sattlecker et al., 2015; Sattlecker et al. 2017; Žák et al., 2017). Results of specific researches confirmed the dependence between the intensity of the physical load and the athlete´s postural stability in the standing shooting position, especially in anterior-posterior axis (Gallicchio et al., 2018; Haug, 2018; Ihalainen et al., 2018; Laaksonen et al., 2018; Sattlecker et al., 2015; Sattlecker et al., 2017; Vonheim, 2012; Žák et al., 2017). Høydal and Nord (2017) presented the importance of heart rate monitors during training by junior biathletes. They meant that heart rate control is one of the predictors of successful shooting.

Our current study that is presented in this paper follows up the research of Žák et al. (2017) from previous years. This previous research showed the influence of intensity of the physical load on the stability of rifle and the shooting performance. The objective of the study of Žák et al. (2017) was to evaluate observed key parameters of biathlon shooting after one-year systematic training. Shooting skills, balance abilities and the development of strength-endurance abilities were the main components of the training process of participating youth biathletes. The assumption of the study was the improvement of major parts of observed parameters after a one-year intervention. This statement was proved. The observation of a process of triggering and its control was not included in the observed parameters the above mentioned previous study, but many authors regard trigger parameters among the most limiting factors of shooting in biathlon (Haug, 2018; Ihalainen et al., 2018; Sattlecker et al. 2017; Vonheim, 2012; Žák et al., 2016; Žák et al., 2017). This was the reason to include the analysis of finger work on the trigger into our current study apart from data of stability of the rifle in a standing shooting position.

Sattlecker et al. (2013) proved the difference in percentage pressure value on the trigger in the last second before the shot between youth and junior Austrian biathletes and adult ones. His research did not prove the direct dependence between triggering and shooting success, but it confirmed the dependence of targeting stability on postural stability in standing shooting position in both adults and youth categories. Percentage pressure values on the trigger in the last second before the shot were: youth biathletes 75.0%, juniors 90.7% and adults one 91.3%. Sattlecker´s research concluded that the higher pressure value on the trigger before the last 0.5 second before the shot corresponds with higher stability of triggering in the last 0.5 second before the shot.

Žák et al. (2016) put together a so called „Pyramid of biathlon shooting" (Figure 1) and triggering stands on the imaginary peak of it. It means that the athlete who works well with a trigger does not have to be automatically an excellent shooter. It is because all of the components of the shooting technique have to be harmoniously linked to each other. The individual components should be trained separately at first and then, after good acquisition of required skills, they can be joined together. Only key components of endogenous factors were incorporated into the pyramid of biathlon shooting. Exogenous factors influencing final shooting performance were not included into the pyramid.

Figure 1. Pyramid of biathlon shooting (Žák et al., 2016).

Haug (2018) presented specific possibilities for verifying the stability of targeting and triggering during biathlon shooting in his study. He pointed out the instruments Noptel and SCATT that many authors have used in their researches over time as useful.

MATERIAL AND METHODS

Participants

Fifteen national youth and junior elite biathletes (ten women, five men) from a team of the Czech Republic participated in the study. Participants represented the highest national level in the selected category. The mean and standard deviations of age, height, weight, and VO_{2max} were 18.0 ± 1.1 years, 167.7 ± 4.2 cm, 58.6 ± 5.3 kg, 56.3 ± 2.74 $ml.kg^{-1}.min^{-1}$ for women and 17.1 ± 0.42 years, 178.6 ± 4.27 cm, 70.2 ± 9.21 kg, 65.9 ± 3.08 $ml.kg^{-1}.min^{-1}$ for men. The study was approved by the ethics committee and carried out by the Declaration of Helsinki. Before the study, all participants were informed about the aim of the study, nature and also the potential risks of the study. They gave their written informed consent form before the experiment. Participants were informed about the study protocol and about all the methods which were used to assess the shooting performance. The participant was excluded from the study if s/he did not meet these criteria: a) consuming alcohol or caffeine beverages < 24 h prior the tests b) respiratory diseases or other illnesses < 3 weeks before the study c) intense physical activity < 24 h prior the tests d) used antiasthmatic medication < 8h prior the tests

Measures

Preliminary VO_2max test

All participants carried out a continuous incremental exercise test to voluntary exhaustion. The maximal oxygen consumption was measured before the experimental test on a standard treadmill ergometer (Lode Katana). The expired gases were continuously monitored breath by breath through technology system (METALYZER®3B, CORTEX). Before the test, each participant warmed up at a self-selected speed for 5 min. After each one´s warm-up, the initial speed was set up at ten km·h^{-1} with 3 % elevation. Each stage consisted of 50 seconds period. The speed was increased every 50 seconds until reaching 14 km·h^{-1}. Then, only the elevation was changing by 1 % until maximal volitional exhaustion pf each participant. The validity criteria of the test including identification of a plateau (< 150 ml·min^{-1} increase in VO_2) despite increasing speed of running and respiratory exchange ratio > 1.10.

Measurement of pressure on the trigger

SCATT Trigger Sensor STS was used to obtain the information of the effort which the shooter produces when pressing the trigger (Figure 2). All information was graphically displayed in the researcher's computer. During the test, the participant did not provide any feedback or results about their data.

Figure 2. Pressure measuring on the trigger during shooting.

Measurement of rifle dynamics

The rifle dynamics were recorded through the portable accelerometer Go Direct® Acceleration Sensor made by Vernier company. The accelerometer was placed (Figure 3) to the top of the barrel of the biathlon rifle (ANSCHÜTZ, model 1827 F). Accelerometer axis assignment was as follows: Y-axis is 'up/down'; X-axis is along the shooting direction; Z-axis is 'sideways' (in the rifle coordinate frame). The weight of the rifle with the additional harness was 3820 g.

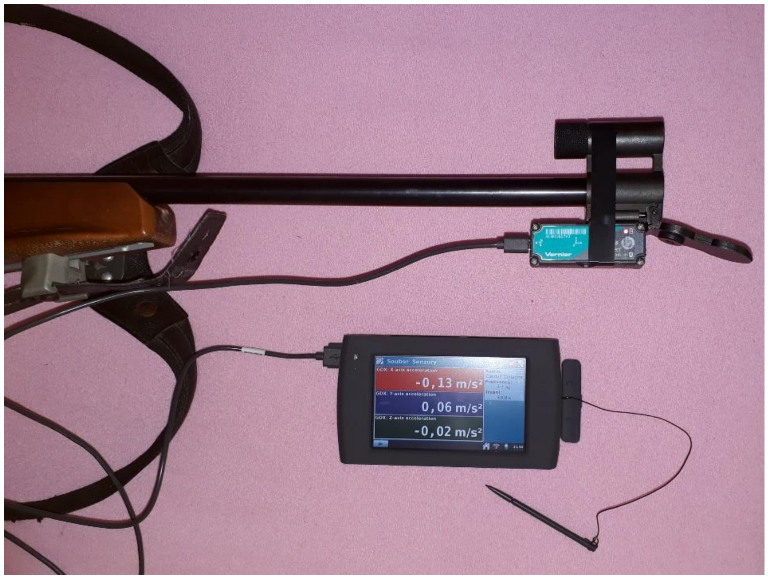

Figure 3. Rifle with accelerometers connected through light weight cable with digital device.

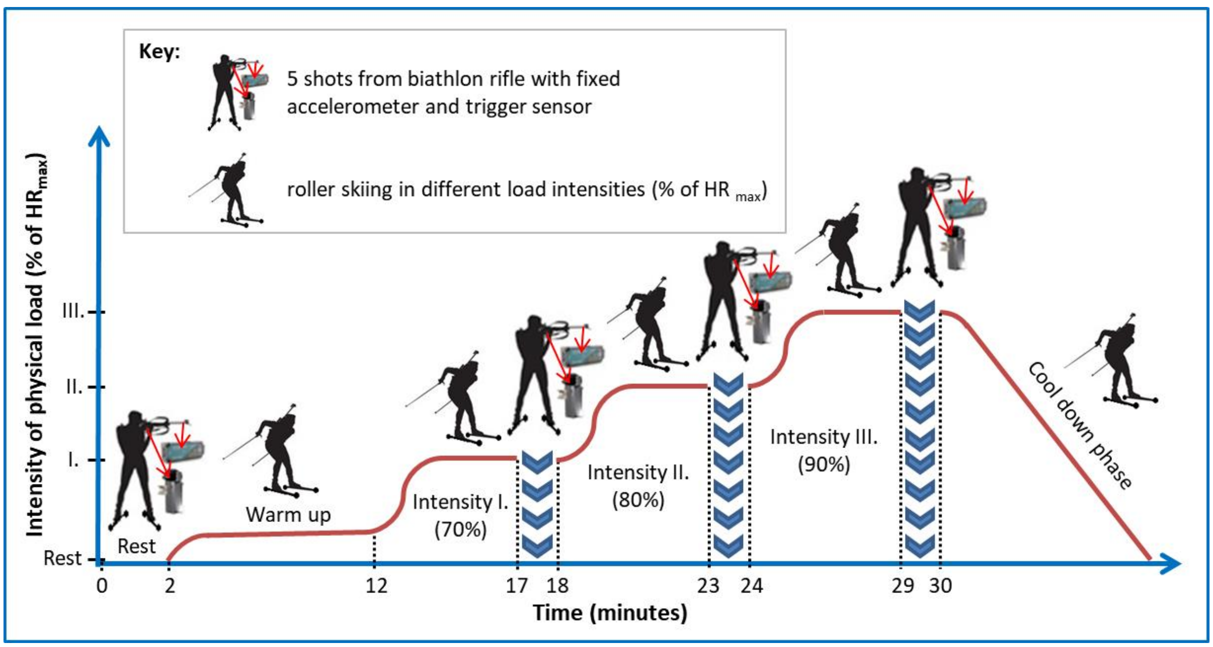

Figure 4. Graphic form of the research test.

Study design

Two weeks before the tests, all participants undertook the test to determine the maximal aerobic power on a cycle ergometer. All tests were conducted at the outdoor certificated biathlon stadium Vysočina Arena near by the city Nové Město na Morave, Czech Republic (600 m above sea level). All testing procedures were done during the summer from 7 a.m to 1 p.m. (the average temperature was 25 °C, the humidity 40 %). Measuring of the dynamic behavior of the rifle was performed in rest and after roller skiing in standing position with using their own biathlons rifle with a fixed accelerometer and trigger sensor for different exercises intensities: Intensity 1 = 70 % of HR_{max} (maximum heart rate), average speed 4.1 – 4.6 $m \cdot s^{-1}$; Intensity 2 =

80 % of $HR_{max,}$ average speed 4.5 – 5.0 $m \cdot s^{-1}$; Intensity 3 = 90 % of HR_{max}, average speed 4.9 – 5.4 $m \cdot s^{-1}$. Each bout consisted from a distance of one km. Before the test, participants calibrated their rifles and practiced shooting. Subsequently, each participant warmed up for 10 min at self-selected speed on roller skies (Figure 4). Participants precisely controlled the requested heart rate which was also controlled by a researcher. All tests were carried out during roller skiing and the participants were instructed to use only skate skiing techniques. After each bout of exercises, participant fired from the standing position at a shooting target (diameter of 11.5 cm, 50 m distance). Each participant was instructed to shoot as accurately as possible in their competition pace. The researcher did not provide any feedback about the results during the all experimental testing.

Statistical analysis

The statistical analyses were conducted using version 12 of the STATISTICA software package (Statsoft Inc, Tulsa, Oklahoma, USA). Descriptive data are summarized as mean ± standard deviation (SD). The assumption of normality was verified using the Shapiro-Wilk statistic. For the reliability analysis, paired sample *t*-tests compared the rifle dynamics between the resting condition and Intensity 3. A two-way analysis of variance was used to compare rifle dynamics for all testing conditions (resting condition, Intensity 1, Intensity 2, Intensity 3). The level of significance was set at $p < .05$.

RESULTS

To assess the disturbance of the rifle produced by the shooting, the portable accelerometer was used during the experimental protocol. The values for Y (up/down) and Z (sideways) axis and measurement of pressure on the trigger are presented in Table 1-6. For each type of intensity five shots were recorded. The data are presented 0.5 and 1 second before the shots for men and women. The values of X axis (along with the shooting direction) were not included in the results due to their negligible value.

Table 1. Descriptive data from rifle dynamics in a group of women (n = 10).

Shooting condition	Y-axis (1 second) ($m.s^{-2}$)	Y-axis (0.5 second) ($m.s^{-2}$)	Z-axis (1 second) ($m.s^{-2}$)	Z-axis (0.5 second) ($m.s^{-2}$)
Rest	0.0957 ± 0.0216	0.0940 ± 0.0234	0,1670 ± 0.0464	0.1584 ± 0,0365
Intensity I	0.0107 ± 0.0174	0.1034 ± 0.0191	0.1736 ±0.0604	0.1632 ± 0.0485
Intensity II	0.1246 ± 0.0505	0.1189 ± 0.0506	0.1836 ± 0.0567	0.1835 ± 0.0647
Intensity III	0.1344 ± 0.0593	0.1258 ± 0.0644	0.2095 ± 0.0696	0.2046 ± 0.0574
p-value (Rest vs. Intensity I vs. Intensity II vs. Intensity III	***NS (.4936)***	***NS (.8495)***	***NS (.4482)***	***NS (.248755)***

NS: not statistically significant; p < .05.

Table 2. Descriptive data from rifle dynamics in a group of men (n = 5).

Shooting condition	Y-axis (1 second) ($m.s^{-2}$)	Y-axis (0.5 second) ($m.s^{-2}$)	Z-axis (1 second) ($m.s^{-2}$)	Z-axis (0.5 second) ($m.s^{-2}$)
Rest	0.1108 ± 0.0209	0.1179 ± 0.0201	0.2003 ± 0.0491	0.2084 ± 0.0477
Intensity I	0.1210 ± 0,0181	0.1202 ± 0.0216	0.2359 ± 0.0473	0.2482 ± 0.0331
Intensity II	0.1328 ± 0.0222	0.1375 ± 0.0237	0.2728 ± 0.0534	0.2796 ± 0.0547
Intensity III	0.1331 ± 0.0091	0.1333 ± 0.0093	0.2073 ± 0.0343	0.2150 ± 0.0428
p-value (Rest vs. Intensity I vs. Intensity II vs. Intensity III	***NS (.2919)***	***NS (.4286)***	***NS (.1546)***	***NS (.1401)***

NS: not statistically significant; p < .05.

Table 3. Descriptive data from measurement of pressure on the trigger in a group of women (n = 10).

Shooting condition	Pressure value (1 second) (%)	Pressure value (0.5 second) (%)
Rest	74.7 ± 10.04	78.8 ± 10.52
Intensity I	71.5 ± 12.08	77.4 ± 12.47
Intensity II	73.6 ± 11.28	78.6 ± 12.73
Intensity III	71.6 ± 12.58	78.3 ± 11.12
p-value (Rest vs. Intensity I vs. Intensity II vs. Intensity III	***NS (.9062)***	***NS (.9923)***

NS: not statistically significant; p < .05.

Table 4. Descriptive data from measurement of pressure on the trigger in a group of men (n = 5).

Shooting condition	Pressure value (1 second) (%)	Pressure value (0.5 second) (%)
Rest	86.4 ± 5.50	90.4 ± 2.70
Intensity I	84.8 ± 5.06	89.8 ± 2.28
Intensity II	85.8 ± 5.16	89.8 ± 3.63
Intensity III	80.2 ± 6.76	87.8 ± 2.38
p-value (Rest vs. Intensity I vs. Intensity II vs. Intensity III	***NS (.3308)***	***NS (.5008)***

NS: not statistically significant; p < .05.

Table 5. Comparison of values from the measurement of pressure (%) on the trigger for resting conditions with Intensity III.

Shooting condition	Women	Men
Rest	78.8 ± 10.52	90.4 ± 2.70
Intensity III	78.3 ± 11.12	87.8 ± 2.38
p-value	***NS (.6652)***	***NS (.1861)***

NS: not statistically significant; p < .05.

Table 6. Comparison of values from the measurement of rifle dynamics for resting conditions with Intensity III (Z-axis, 0.5 seconds before shooting).

Shooting condition	Women	Men
Rest	0.1584 ± 0.0365	0.2084 ± 0.0477
Intensity III	0.2046 ± 0.0574	0.2150 ± 0.0428
p-value	****.0233***	***NS (.7927)***

*NS: not statistically significant; *p < .05.*

DISCUSSION

The aim of the study was to analyse and find out potential dependence between the dynamics rifle stability during targeting and percentage pressure value on the trigger 1 second and 0.5 second before the shot in different intensities of the physical load. The data used in our research showed that the dynamic rifle stability is not influenced by exercise intensity neither in the men nor women group. However, our study demonstrated that the rifle stability is better in time 0.5 second before the shot than in time 1 second before the shot. It means that the athlete's control over his rifle during targeting is more effective in time of the approaching shot than in previous time. This fact about the rifle stability was valid during the measurement in all three intensities of the physical load and in resting condition too. Moreover, in the descriptive results it is possible to notice the fact that increasing intensity of the physical load corresponds with increased movement of the rifle, respectively worse rifle stability. Consequently, the increased heart rate correlates with worse targeting stability as has been confirmed in previous researches of several authors (Gallicchio et al., 2018; Haug, 2018; Ihalainen et al., 2018; Laaksonen et al., 2018; Sattlecker et al., 2015; Sattlecker et al., 2017; Vonheim, 2012; Žák et al., 2017). In our study, the statistical significance was only showed in comparing parameters of dynamics rifle stability during targeting in resting conditions against these parameters in exercise Intensity 3 in the women group.

The measurement of percentage pressure value on the trigger during the last second before the shot showed the good work of the athlete's finger on the trigger in both men and women groups during resting condition and in all intensities of the physical load too. In comparison with the Austrian study, where biathletes of the same age category participated (Sattlecker et al., 2013), there are resulting values of measured parameters at a similar level. According to the resulting data it is evident that the average pressure value on the trigger is increasing between the last 1 second and the last 0.5 second before the shot. For the coach, the most important and determinative parameters are the resulting data of the Intensity 3 because the level of heart rate in this exercise intensity corresponds with the HR level in the race. The measurement in our study showed that participants are able to work with their fingers on the triggers in similar quality in the racing load as well as without the previous physical load.

During the pilot measurement, by using SCATT and the Trigger Sensor STS, it was proved that the increasing pressure on the trigger has the negative impact on the rifle stability. In other words, the increase of pressure on the trigger during targeting in last second before the shot causes much more extensive destabilization of the rifle than the reduction of the rifle stability would be in situation when the biathlete's pressure on the trigger would be as maximal as possible and constant in time 1 second and more before the shot.

In overall data evaluation, no direct dependence of the pressure value on the trigger on the shooting success was found. One reason of this finding can be the fact that many factors determine the final success of the shooting performance, as has been mentioned above.

CONCLUSION

Fifteen young Czech biathletes of age corresponding to the youth and junior categories (ten women with parameters of age, height, weight and $VO_{2max:}$ 18.0 ± 1.1 years, 167.7 ± 4.2 cm, 58.6 ± 5.3 kg, 56.3 ± 2.74 $ml.kg^{-1}.min^{-1}$ and five men with the same parameters: 17.1 ± 0.42 years, 178.6 ± 4.27 cm, 70.2 ± 9.21 kg, 65.9 ± 3.08 $ml.kg^{-1}.min^{-1}$) participated in the study. The experience each of them with the long rifle shooting has been two years minimally. They had acquired basic skills of the shooting with an air rifle during the children's category, which all participants have completed. The previous study (Žák et al., 2017) showed that the progress in the postural stability, the targeting stability and shooting performance is considerable during the first year of shooting training with a long rifle (in the youth category). The progress in these parameters is not so intense in following years; the shooting performance stabilizes at the turn of the youth to the junior category. The training process in this older athlete´s age is focused on details of shooting skills, and the right technique of triggering is one of them.

We recognized a health handicap (the problem with fine motor skills) in one of the biathletes thanks to her participation in the study. This athlete was not able to control and perceive the movement and the strength of her finger on the trigger. We recommended to her an examination by a specialist and the cooperation with physiotherapists.

Finally, we must mention the limiting factors of our study. Firstly, a low number of participants (fifteen athletes) can be considered as one of them. This was caused by the strict rules of the selection of the biathletes to the study which we mentioned above. The next limiting factor was the season of the measurement. It was necessary to do it during summertime because the quality of measurement would be negatively influenced by frozen fingers of biathletes and other similar difficulties during winter.

Our study shows that the measurement on combination of the above mentioned instruments (the SCATT Shooter Training System with connected Trigger Sensor STS and the portable accelerometer Go Direct® Acceleration Sensor placed to the top of the barrel of the biathlon rifle) can be a well usable instrument to diagnose and train the work of the biathlete on the trigger while monitoring the postural stability. The coach is unable to identify the pressure value on the trigger and movement of the rifle by seeing with the naked eyes the finger of the biathlete during the shooting. This shows that the utilization of these diagnostic instruments in a common training process can be widely recommended to biathlon trainers. Thanks to monitoring the work of the athlete's finger on the trigger and the long-term systematic training of this parameter, an improvement in shooting performance can be expected.

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