THE PERFORMANCE STRUCTURE OF INDIVIDUAL COMPETITION IN BIATHLON

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Original scientific paper
DOI 10.26582/k.54.1.16

Abstract:

Individual biathlon competition as an event consists of a number of segments (variables), i.e. cross-country skiing time, range time, so-called time difference, and shooting accuracy. The study analysed the interrelations of these variables and their correlations with competitive performance at the Biathlon World Championship individual for men. Regression analysis showed that total cross-country skiing time was the most important determinant of competitive performance (55%). Total shooting performance prone and standing explains 39.5%, total range time accounts for 5% of the criterion variable, and time difference for 0.5%. The contestants hit 80.5% of all targets in this competition. Factor analysis determined seven factors that logically completed the competition outcome in a biathlon individual competition. These factors are: cross-country skiing performance; shooting time and range time; time difference; accuracy shooting 1 and total time in lap 1; accuracy shooting 2 and total time in lap 2; accuracy shooting 4 and total time in lap 4; and accuracy shooting 3 and total time in lap 3. Although we found a somewhat dominant contribution of the cross- country skiing itself to the final competitive performance in this competition, shooting accuracy is also very important in an individual biathlon competition. The results of men's individual biathlon competitions at the last Olympics and World Championships show that it is still possible to win a medal with only one missed shot (two missed shots can only be afforded by the rare biathletes who are extremely fast skiers).

Key words: *biathlon competition, competition variables, performance analysis, men*

Introduction

Biathlon is a winter sport that combines skate-style cross-country skiing and small-calibre rifle shooting. The first Biathlon World Championship (BWCH) was held in 1958. Biathlon debuted at the 1960 Winter Olympics (Lehotan, Magyar, & Lange, 2008). Today, the Olympic Games schedule contains four singles competitions (individual, sprint, pursuit, and mass start) and two team competitions (a relay race – men/women, and mixed relay – teams consisting of two men and two women skiers).

The individual competition is the oldest biathlon discipline. It was first performed at the World Championship in 1958 and at the Olympics in 1960 (Nitzsche, 1989). The men's run is 20 km long (5 laps of approx. 4 km). The shooting takes place four times in a row at 50 m distant targets, prone (target diameter 4.5 cm), standing (target diameter 11.5 cm), and then prone and standing again. Competitors receive one-minute time penalty for each missed shot. The winner is determined by the best time including the added penalty minutes. The biathletes start individually, in a time interval of 30 seconds. Competition rules in biathlon require competition tracks, where flat areas, ascents, and descents alternate (IBU, 2019), and this requires from competitors to frequently change their skiing technique (Holmberg, 2015).

Biathlon is classified as an endurance sport in which aerobic energy production is a vital determinant of competitive performance, and where endurance performance depends on both aerobic and anaerobic factors, together with exercise economy and/or gross mechanical efficiency (Bassett, & Howley, 2000; Joyner, & Coyle, 2008). High values of maximum oxygen consumption (VO_2max) were measured in top biathletes – in men, over 80 and in women, over 65 $ml\cdot kg^{-1}\cdot min^{-1}$ (Tønnessen, Haugen, Hem, Leirstein, & Seiler, 2015).

The following information is provided by Laaksonen, Jonsson and Holmberg (2018) regarding biathlon training: "The best biathletes perform 700–900 h of physical training annually, including endurance training of approximately 80% at low, 4–5% at moderate, and 5–6% at high intensity, together with 10% of strength and speed training. During a single season, world-class biathletes fire more than 20.000 shots during more than 200 training sessions, approximately 60% of which involve shooting combined with endurance training [9.000 (75%) at low, 2.000 (15%) at moderate, and 1.250 (10%) at high intensity], i.e., shooting between bouts of skiing or, to lesser extent, running. The remainder of these more than 20.000 shots are fired at rest, focusing on improving the accuracy and/or the speed of preparation, shooting, and exit."

Competitive performance in biathlon depends on the cross-country skiing speed, range time, shooting time, and shooting accuracy (shooting time is a part of range time, while shooting performance consists of shooting accuracy and shooting time). The question raised is what is the impact of each of these segments of an individual race on a biathlete's competitive performance? An answer to this question would help to improve the effectiveness of the training process for biathlon competitors.

Luchsinger, Kocbach, Ettema, and Sandbakk (2018a) have shown that approximately 60% of overall performance in biathlon sprint competitions is determined by skiing speed and that in individual competitions, where each missed shot results in a 1-min penalty, shooting performance is probably more important. Skattebo and Losnegard (2018) state that time on the shooting range and shooting time have very little effect on ultimate competitive success, as these times are usually similar in top biathletes (also in different competitive disciplines). The most important factors of the final result are both the time of cross-country skiing and the accuracy of shooting.

The aim of the study was to determine the latent structure of captured competition variables on a biathlon individual competition performance. The study analysed the correlation among individual variables and the contribution of individual sets of variables to the explanation of competitive performance in this sporting event.

The novelty of this study is that we studied the relationship between a large number of variables (we systematically analysed 32 variables), which accurately represent individual sections of the biathlon competition track at a distance of 20 km. Factor analysis gave detailed insight into the structure of this competition. With the results of the study, we also wanted to verify the claim of the authors (Luchsinger, Kocbach, Ettema, & Sandbakk, 2018b) that at the general level, shooting performance is more important at a distance of 20 km than in sprint competitions.

Methods

Participants

The cross-sectional study included 115 male competitors from 39 countries who took part in the individual competition at the 2013 World Biathlon Championship in Nove Mesto, the Czech Republic. We decided to study this competition because the competition conditions were constant (i.e., snow conditions, weather conditions, and wind), and because this study could in the future be part of research on biathlon competitions over a longer period of time (e.g., a period of 10 years).

Instruments

The variables were derived from the database of the companies: Siwidata (electronic timing) and Hora 2000 E (electronic target system). These data are the official results of the competition and are publicly available on the website of the International Biathlon Union (IBU, 2013).

Dependent variable

TT – total race time (competition result). The criterion variable is determined by the time elapsed between the start and the finish line (this time consists of cross-country skiing time, range time and the time difference) and potential time penalties for missed shots.

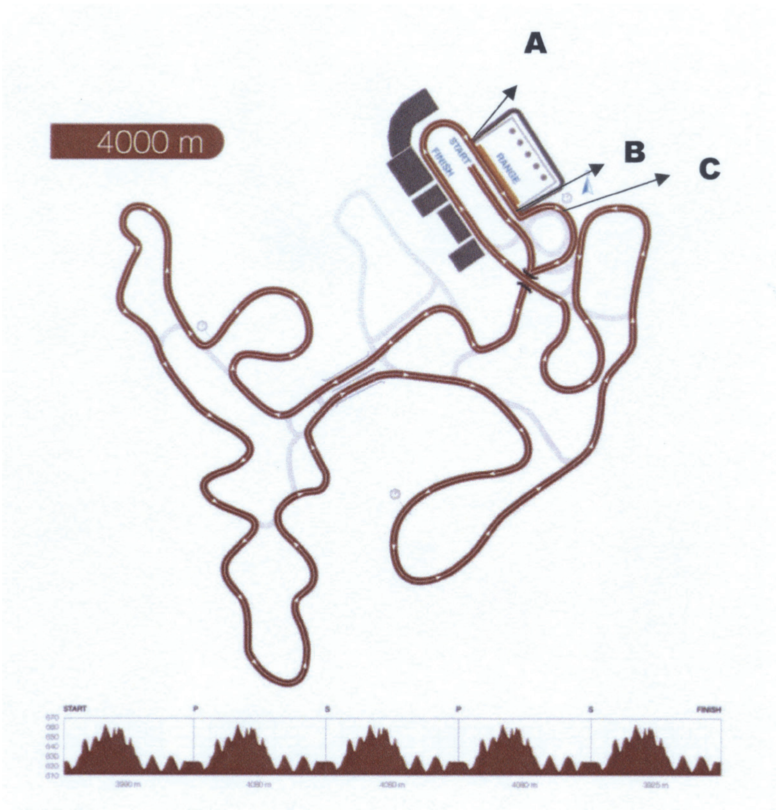
Independent variables

Cross-country skiing times

TCT – total cross-country skiing time (does not include range time). It means the time spent by the competitor in the competition from start to finish only in the cross-country skiing. Cross-country skiing time does not include time at the shooting range (time spent to make the last 10 m before the shooting range to the shooting lane, time of shooting, and time spent from the shooting lane to the 10 m point after the range). Cross-country skiing time was analysed for each loop separately: L1CT – lap 1 cross-country skiing time (from the start to mid-lap time after the range), L2CT – lap 2 cross-country skiing time (from mid-lap time after the range to mid-lap time after the range), L3CT – lap 3 cross-country skiing time, L4CT – lap 4 cross-country skiing time, L5CT – lap 5 cross-country skiing time (from mid-lap time after the range to the finish line).

Range times

TRT – total range time (time spent on the shooting range during four shooting bouts). Range time is measured from the 10 m point before the range to the point which is 10 m after the range. Range time covers the time spent from the 10 m



Note. A = 10 m before the shooting range, B = 10 m after the shooting range, C = intermediate time after the shooting range.

Biathlon course	Length	Altitude difference	Max. ascent	Total of ascents
Lap 1	3990 m	50 m	28 m	137 m
Lap 2	4080 m	50 m	28 m	141 m
Lap 3	4080 m	50 m	28 m	141 m
Lap 4	4080 m	50 m	28 m	141 m
Lap 5	3825 m	50 m	28 m	135 m
Total	20155 m	50 m	28 m	695 m

Figure 1. Graphical display of the individual competition course at the 2013 World Biathlon Championship in Nove Mesto, the Czech Republic (Biathlon NMNM, 2013).

point before the range to the shooting lane, time of shooting, and the time spent from the shooting place to the 10 m point after the range. Range time was analysed for each lap separately: L1RT – lap 1 range time (from the 10 m point before the range to the 10 m point after the range), L2RT – lap 2 range time, L3RT – lap 3 range time, L4RT – lap 4 range time.

Shooting times

TST – total shooting time (time spent shooting in two prone and two standing positions). Shooting time is the time a competitor spends shooting only. It is measured from the moment when the competitor lays the poles on the ground to the moment when the competitor picks up the poles after five shots have been fired. Each shooting bout was analysed separately: ST1 – shooting bout time 1 (prone), ST2 – shooting bout time 2 (standing), ST3 – shooting bout time 3 (prone), and ST4 – shooting bout time 4 (standing).

Time difference

TTD – total time difference. Time difference in the competition is measured from the 10 m point after the shooting range to mid-lap time after the shooting range (at the end of each lap). Time difference per loop was also analysed: L1TD – lap 1 time difference (from the 10 m point after the shooting range to mid-lap time after the shooting range), L2TD – lap 2 time difference, L3TD – lap 3 time difference, and L4TD – lap 4 time difference.

Lap times

The total time of all five laps and potential minute penalties for missed shots means the competitor's total race time (TT) and defines the competitor's ranking. Lap times were analysed separately: L1TT – lap 1 total time (from the start to mid-lap time after the range), L2TT – lap 2 total time (from mid-lap time after the range to mid-lap time after the range), L3TT – lap 3 total time, L4TT

– lap 4 total time, and L5TT – lap 5 total time (from mid-lap time after the range to the finish line).

Missed shots

TMS – total number of missed shots prone and standing. Missed shots in specific shooting bouts were analysed: S1MS – shooting 1 missed shots (prone), S2MS – shooting 2 missed shots (standing), S3MS – shooting 3 missed shots (prone), and S4MS – shooting 4 missed shots (standing).

Statistical procedure

The data were processed using SPSS Statistics software. Basic statistical parameters were computed for all the variables. The correlation among independent variables and the correlation between the independent variables and the dependent variable were tested using Pearson's correlation coefficient. A factor analysis was used to determine the latent structure of the variables. The inherent relationship between the block of independent variables and the independent variable (competition result) was tested using a multiple regression analysis.

Results

Table 1 shows the basic statistical characteristics of variables in an individual competition.

Total race time (TT): The winner completed the course in 2983.0 seconds, while the last competitor to cross the finish line completed the course in 4337.7 seconds, or approximately 23 minutes behind.

Table 1. Statistical characteristics of the variables

VARIABLES	UNIT	MIN	MAX	M	SD	CV
L1CT – cross-country skiing time, lap 1	second	521.9	650.8	566.8	28.3	5%
L1TD – time difference, lap 1	second	3.8	6.3	4.7	0.5	10%
L1RT – range time, lap 1	second	47.1	81.5	60.8	6.4	11%
L1TT – total time, lap 1	second	582.4	913.9	672.0	69.8	10%
S1MS – missed shots, shooting 1 (prone)	shot	0	4	0.76	0.87	116%
ST1 – shooting bout time 1 (prone)	second	22	52	33.8	5.7	17%
L2CT – cross-country skiing time, lap 2	second	539.3	685.8	589.3	35.7	6%
L2TD – time difference, lap 2	second	3.7	5.5	4.4	0.4	8%
L2RT – range time, lap 2	second	47.6	79.9	57.7	6.4	11%
L2TT – total time, lap 2	second	590.7	930.9	707.6	80.0	11%
S2MS – missed shots, shooting 2 (standing)	shot	0	4	1.01	0.97	96%
ST2 – shooting bout time 2 (standing)	second	21	54	30.6	5.56	18%
L3CT – cross-country skiing time, lap 3	second	543.0	704.6	605.0	39.9	7%
L3TD – time difference, lap 3	second	4.0	6.4	4.9	.44	9%
L3RT – range time, lap 3	second	51.2	83.7	63.4	6.0	10%
L3TT – total time, lap 3	second	604.1	981.5	718.7	82.6	11%
S3MS – missed shots, shooting 3 (prone)	shot	0	4	0.83	0.93	111%
ST3 – shooting bout time 3 (prone)	second	25	54	35.4	5.1	15%
L4CT – cross-country skiing time, lap 4	second	555.5	728.2	616.8	39.8	6%
L4TD – time difference, lap 4	second	3.8	5.4	4.5	0.4	8%
L4RT – range time, lap 4	second	45.8	81.0	58.7	6.7	11%
L4TT – total time, lap 4	second	624.7	974.1	753.9	81.8	11%
S4MS – missed shots, shooting 4 (standing)	shot	0	4	1.30	0.97	74%
ST4 – shooting bout time 4 (standing)	second	22	53	31.2	5.9	19%
L5CT – cross-country skiing time, lap 5	second	523.7	698.8	585.1	40.4	7%
L5TT – total time, lap 5	second	523.7	698.8	585.1	40.4	7%
TCT – total cross-country skiing time	second	2690.3	3462.1	2963.1	180.6	6%
TTD – total time difference	second	15.9	23.3	18.6	1.3	7%
TST – total shooting time of four bouts	second	99	199	131.0	18.1	14%
TRT – total range time	second	201.5	316.7	240.6	21.9	9%
TMS – total number of missed shots	shot	0	12	3.90	2.4	61%
TT – total race time	second	2983.0	4337.7	3438.4	293.8	8%

Note. MIN – minimum value, MAX – maximum value, M – mean, SD – standard deviation, CV – coefficient of variation.

Mean race time (3438.4 seconds) was approximately eight minutes slower than the winner's result. Only one competitor finished the competition without a missed shot (and thus no time penalty) at the 21st place. Of the 10 first-ranked competitors, six missed one shot (including the first three placements), while the others missed two (IBU, 2013).

Cross-country skiing times (L1CT, L2CT, L3CT, L4CT, L5CT, TCT): A comparison of individual times of cross-country skiing was possible between the second, third, and fourth laps (these laps have the same length). On average, the skiers were the fastest on the second lap (589.3 seconds) and slowest on the fourth lap (616.8 seconds). The slower average times are consequence of the fatigue of the competitors, and also of the gradual deterioration of the gliding properties of the skis.

Range times (L1RT, L2RT, L3RT, L4RT, TRT): The time spent on the shooting range averaged at 240.6 seconds. Competitors stayed at the shooting range for an average of 62.1 seconds in the case of shooting while lying (prone), and for an average of 58.2 seconds for shooting while standing. This indicates that prone shooting on average requires longer preparation. The competitors with the fastest and slowest range times were separated by a relatively high time difference (115.2 s). Similarly, high is the time difference between the fastest competitor on the range and the mean range time (39.1 s).

Shooting times (ST1, ST2, ST3, ST4, TST): The fastest shooter finished his shooting in a prone position in 22 seconds, while the average prone shooting time was 34.6 seconds. The average standing shooting time was 3.7 seconds shorter than the average prone shooting time, while the fastest standing shooting was completed in 21 seconds.

Missed shots (S1MS, S2MS, S3MS, S4MS, TMS): The competitors cleared an average of 80.5% targets. Shooting in a prone position (average shots missed – 0.76 and 0.83) was more efficient than shooting in a standing position (average shots missed – 1.01 and 1.30). All five shots were scored within each individual shooting round, while the worst result of a single shooting round represented four missed shots. Only two competitors finished the competition with all targets cleared. The worst achievement was 12 missed shots (IBU, 2013).

Time differences (L1TD, L2TD, L3TD, L4TD, TTD): Due to the relatively short distance (from the 10 m point after the shooting range to mid-lap time after the shooting range), there was no significant difference in time between the competitors. The biggest difference between the average times and the fastest biathlete was 0.9 seconds in the first and third rounds.

Correlation analysis

Table 2 represents the correlations between the variables of a biathlon individual competition. All correlations above 0.18 are statistically significant with a confidence level of 95%.

Table 2a. Correlations among the variables

	L1CT	L1TD	L1RT	L1TT	S1MS	ST1	L2CT	L2TD	L2RT	L2TT	S2MS	ST2	L3CT	L3TD	L3RT
L1TD – time difference, lap 1	.32**														
L1RT – range time, lap 1	.53**	.30**													
L1TT – total time, lap 1	.66**	.24**	.61**												
S1MS – missed shots, shooting 1 (prone)	.27**	.11	.40**	.90**											
ST1 – shooting bout time 1 (prone)	.43**	.19*	.97**	.56**	.39**										
L2CT – cross-country skiing time, lap 2	.93**	.34**	.55**	.61**	.24**	.44**									
L2TD – time difference, lap 2	.63**	.41**	.38**	.40**	.15	.30**	.67**								
L2RT – range time, lap 2	.51**	.26**	.60**	.42**	.20*	.55**	.52**	.32**							
L2TT – total time, lap 2	.70**	.30**	.44**	.49**	.22*	.37**	.69**	.45**	.63**						
S2MS – missed shots, shooting 2 (standing)	.34**	.18*	.21*	.25**	.13	.19*	.28**	.18*	.43**	.89**					
ST2 – shooting bout time 2	.36**	.19*	.51**	.32**	.16	.48**	.36**	.12	.94**	.51**	.38**				
L3CT – cross-country skiing time, lap 3	.92**	.31**	.55**	.63**	.27**	.45**	.97**	.67**	.54**	.69**	.30**	.38**			
L3TD – time difference, lap 3	.41**	.70**	.32**	.33**	.18*	.23*	.41**	.53**	.24**	.34**	.20*	.12	.41**		
L3RT – range time, lap 3	.50**	.29**	.76**	.58**	.41**	.71**	.55**	.41**	.54**	.40**	.15	.44**	.57**	.30**	
L3TT – total time, lap 3	.68**	.25**	.39**	.57**	.34**	.32**	.75**	.48**	.34**	.58**	.30**	.19*	.77**	.38**	.55**
S3MS – missed shots, shooting 3 (prone)	.30**	.12	.10	.34**	.27**	.08	.35**	.20*	.06	.32**	.22*	-.03	.37**	.23*	.29**
ST3 – shooting bout time 3	.38**	.16	.71**	.50**	.38**	.70**	.42**	.31**	.46**	.30**	.10	.39**	.45**	.15	.94**
L4CT – cross-country skiing time, lap 4	.92**	.29**	.55**	.62**	.26**	.45**	.96**	.66**	.54**	.71**	.32**	.37**	.99**	.42**	.57**

L4TD – time difference, lap 4	.69**	.34**	.40**	.43**	.16	.33**	.70**	.70**	.34**	.50**	.22*	.16	.69**	.52**	.41**
L4RT – range time, lap 4	.50**	.19*	.62**	.41**	.19*	.56**	.53**	.42**	.74**	.51**	.30**	.64**	.53**	.24**	.64**
L4TT – total time, lap 4	.73**	.15	.43**	.52**	.24**	.38**	.73**	.46**	.36**	.58**	.31**	.21*	.70**	.31**	.39**
S4MS – missed shots, shooting 4 (standing)	.34**	-.01	.17	.26**	.14	.16	.30**	.15	.06	.27**	.18*	-.03	.25**	.12	.09
ST4 – shooting bout time 4	.38**	.11	.54**	.33**	.17	.51**	.40**	.29**	.70**	.44**	.29**	.66**	.39**	.09	.57**
L5CT – cross-country skiing time, lap 5	.91**	.32**	.51**	.61**	.26**	.41**	.95**	.67**	.51**	.70**	.32**	.33**	.97**	.43**	.53**
TCT – total cross-country skiing time	.95**	.32**	.55**	.63**	.26**	.44**	.98**	.68**	.54**	.71**	.32**	.37**	.99**	.42**	.56**
TTD – total time difference	.61**	.80**	.43**	.43**	.18*	.31**	.63**	.79**	.35**	.48**	.24**	.18*	.62**	.87**	.43**
TST – total shooting time of four bouts	.48**	.20*	.84**	.53**	.34**	.82**	.50**	.31**	.82**	.51**	.30**	.78**	.51**	.18*	.81**
TRT – total range time	.60**	.30**	.87**	.58**	.35**	.81**	.63**	.44**	.84**	.58**	.32**	.74**	.63**	.32**	.85**
TMS – total number of missed shots	.49**	.16	.34**	.67**	.59**	.32**	.47**	.27***	.30**	.68**	.62**	.19*	.47**	.29**	.36**
TT – total race time	.87**	.30**	.57**	.76**	.47**	.49**	.88**	.58**	.54**	.81**	.52**	.38**	.88**	.42**	.58**

Note. *p<.05; **p<.01

Table 2b. Correlations among the variables

	L3TT	S3MS	ST3	L4CT	L4TD	L4RT	L4TT	S4MS	ST4	L5CT	TCT	TTD	TST	TRT	TMS
S3MS – missed shots, shooting 3 (prone)	.87**														
ST3 – shooting bout time 3	.45**	.25**													
L4CT – cross-country skiing time, lap 4	.78**	.39**	.45**												
L4TD – time difference, lap 4	.52**	.24**	.30**	.71**											
L4RT – range time, lap 4	.42**	.18*	.57**	.52**	.41**										
L4TT – total time, lap 4	.63**	.40**	.30**	.72**	.60**	.52**									
S4MS – missed shots, shooting 4 (standing)	.31**	.27**	.05	.27**	.31**	.26**	.86**								
ST4 – shooting bout time 4	.31**	.12	.53**	.38**	.22*	.95**	.41**	.22*							
L5CT – cross-country skiing time, lap 5	.79**	.43**	.41**	.97**	.71**	.53**	.73**	.30**	.38**						
TCT – total cross-country skiing time	.77**	.38**	.43**	.99**	.72**	.53**	.73**	.29**	.39**	.98**					
TTD – total time difference	.49**	.24**	.28**	.62**	.76**	.37**	.45**	.16	.21*	.64**	.64**				
TST – total shooting time of four bouts	.39**	.13	.80**	.50**	.31**	.85**	.40**	.13	.84**	.47**	.50**	.30**			
TRT – total range time	.49**	.18*	.77**	.63**	.45**	.88**	.50**	.17	.81**	.60**	.63**	.46**	.97**		
TMS – total number of missed shots	.72**	.69**	.30**	.49**	.37**	.37**	.72**	.64**	.32**	.52**	.50**	.33**	.35**	.40**	
TT – total race time	.86**	.58**	.47**	.89**	.65**	.57**	.84**	.50**	.45**	.90**	.90**	.58**	.55**	.66**	.82**

Note. *p<.05; **p<.01

Total race time (TT) relative to cross-country skiing times: A high correlation between total race time (TT) and TCT – total cross-country skiing time (r = 0.90, p=.000) indicates that cross-country skiing time is one of the most important competition segments determining the final performance. High-ranking competitors finished the race with better cross-country skiing times. Cross-country skiing times in various laps also show a similarly high correlation with the total race time (r = 0.87, p=.000 – lap one; r = 0.88, p=.000 – lap two; r = 0.88, p=.000 – lap three; r = 0.89, p=.000 – lap four; and r = 0.90, p=.000 – lap five).

Total race time (TT) relative to the number of missed shots: In addition to the cross-country skiing speed, shooting accuracy is the most important determinant of the final score. In the studied World Cup individual competition, the correlation between the number of missed shots (TMS) and the final result was r = 0.82, p=.000. The correlation between the hits of individual shots and the final competitive performance ranges between r = 0.47, p=.000 and r = 0.58, p=.000.

Total race time (TT) relative to shooting time: Top-performing biathletes are faster shooters, and vice versa. However, the correlation between total race time and the total time of four shooting bouts (TST) is not particularly high (r = 0.55, p=.000), which indicates that the shooting speed does not have a significant impact on the final outcome.

Nevertheless, in the tough competition of elite biathletes, the speed of shooting might be very important since it can create considerable competitive advantage. In addition, the fastest shooter in the competition needed about 32 seconds less time to complete his four shooting bouts than average shooters. Time of shooting in prone position showed higher correlation with the criterion (r = 0.49, p=.000 and r = 0.47, p=.000) than the time of shooting in the standing position (r = 0.38, p=.000 and r = 0.45, p=.000).

The correlation between total race time (TT) and total range time (TRT) was r = 0.66, p=.000. Top-performing biathletes needed less time to leave the range zone (10 m before and 10 m after the range).

Cross-country skiing time relative to the number of missed shots: The correlation between the total cross-country skiing time (TCT) and the total number of missed shots (TMS) was r = 0.50, p=.000. Within individual laps, the speed of the cross-country skiing and the accuracy of shooting showed lower correlations (lap one r = 0.27, p=.003; lap two r = 0.28, p=.002; lap three r = 0.37, p=.000; and lap four r = 0.27, p=.004).

The number of missed shots relative to shooting time: More reliable shooters were also statistically significantly faster shooters. The correlations indicated that the speed of shooting had a relatively minor impact on the shooting efficiency. The correlation between total shooting time (TST) and total number of missed shots (TMS) was r = 0.35, p=.000. At competitions, certain competitors will shoot very fast, achieving high target clearage, while other competitors shoot more slowly but with equally high shooting accuracy.

Correlations between hits and firing speed per lap ranged between r = 0.22, p=.020 and r = 0.39, p=.000.

The relationship between firing accuracy and timing of individual laps: Within individual laps, these correlations were very high and ranged from r = 0.86, p=.000 to r = 0.90, p=.000 (S1MS: L1TT). Each lap time included also potential minute penalties for missed shots.

The relationship between shooting accuracy in the prone and standing positions: The correlation between the two shootings in prone was relatively small (r = 0.27, p=.003), as was the correlation between the two shootings in the standing position (r = 0.18, p=.048). Hypothetically, it can be assumed that poorer shooters in prone position are also poor shooters in a standing position, and vice versa. However, this assumption is negated by the established correlation between the number of missed shots in prone and standing positions. The correlation between the first shooting in prone position and both shootings in standing position was statistically insignificant (r = 0.13, p=.177 and r = 0.14, p=.134), while the correlations between the second shooting in prone position and both shootings in standing positions were slightly higher (r = 0.22, p=.020 and r = 0.27, p=.003).

The latent structure of the individual competition variables was determined using a factor analysis. Based on the K-G criterion, seven factors were obtained. The first factor covered 51.09% of total variance (Table 3).

The factor structure matrix was obtained using the oblimin rotation. Projections of the cross-country skiing time and total race time (TT) variables dominated on the first factor. The most important impact on the final performance at the Biathlon World Cup's individual competition is attributable to the impact of the cross-country skiing performance. The second factor was dominated by variable projections of shooting time and range time, the third factor by variable projections of time difference, the fourth factor was dominated by variable projections of accuracy shooting 1 and total time in lap 1, the fifth factor was dominated by variable projections of accuracy shooting 2 and total time in lap 2, the sixth factor was dominated by variable projections of accuracy shooting 4 and total time in lap 4, and the seventh factor was dominated by variable projections of accuracy shooting 3 and total time in lap 3.

Table 4 shows the greatest correlation between the first and third factor, and the lowest between the fourth and fifth factor.

The correlation between the block of predictor variables and the criterion variable was determined on the basis of a regression analysis (Table 5).

On the basis of results in Table 5, it is possible to determine the impact of a predictor variable on explaining competitive performance (% of competitive performance, as explained by a variable = r x Beta). The block of predictor variables explained 100% of competitive performance in the competition (TT variable). In explaining competitive successfulness, the variable of total cross-country skiing time (TCT) has the largest impact (55%); it is followed by shooting efficiency in terms of missed shots in prone and standing position (39.5%), total range time (5%), and then time difference (0.5%).

Discussion and conclusions

The individual competition held at the Biathlon World Championship was studied with the aim to determine the interrelation of certain independent variables. Furthermore, the study investigated the correlations of specific variables and the block of variables with competitive performance.

Regarding the influence of independent variables on competitive performance, the following findings were made. Total cross-country skiing time is the key determinant of competitive performance in an individual competition since it partially demonstrates very high correlation with the crite-

Table 3. Factor analysis of variables with the oblimin rotation (structure matrix)

Variables	F 1	F 2	F 3	F 4	F 5	F 6	F 7	Com.
Factor of cross-country skiing performance								
TCT – total cross-country skiing time	.99	.47	-.45	.32	.22	.34	.34	.99
L3CT – c.-country skiing time, lap 3	.98	.48	-.44	.32	.21	.29	.34	.97
L4CT – c.-country skiing time, lap 4	.98	.47	-.44	.31	.22	.31	.36	.97
L2CT – c.-country skiing time, lap 2	.97	.47	-.45	.29	.20	.35	.31	.95
L5CT – c.-country skiing time, lap 5	.97	.44	-.46	.29	.22	.36	.39	.96
L1CT – c.-country skiing time, lap 1	.94	.44	-.44	.34	.25	.38	.25	.91
TT – total race time	.86	.50	-.43	.50	.39	.54	.54	.99
Factor of shooting time and range time								
TST – total shooting time of four bouts	.46	.98	-.22	.39	.24	.12	.10	.99
TRT – total range time	.60	.96	-.36	.40	.24	.17	.15	.99
L4RT – range time, lap 4	.50	.88	-.27	.13	.28	.31	.15	.87
ST4 – shooting bout time 4 (standing)	.35	.86	-.12	.09	.31	.25	.11	.83
L1RT – range time, lap 1	.51	.81	-.37	.57	.04	.17	.04	.85
L2RT – range time, lap 2	.51	.81	-.26	.19	.54	.04	-.01	.88
L3RT – range time, lap 3	.52	.81	-.36	.50	-.06	.07	.35	.87
ST1 – shooting bout time 1 (prone)	.41	.79	-.26	.58	.00	.16	.03	.80
ST3 – shooting bout time 3 (prone)	.40	.78	-.21	.48	-.13	.02	.32	.83
ST2 – shooting bout time 2 (standing)	.34	.76	-.12	.14	.56	-.06	-.11	.83
Factor of time difference								
TTD – total time difference	.64	.29	-.97	.19	.09	.22	.18	.99
L3TD – time difference, lap 3	.41	.16	-.90	.19	.09	.16	.18	.83
L1TD – time difference, lap 1	.29	.18	-.87	.13	.12	-.01	.08	.79
L2TD – time difference, lap 2	.72	.30	-.67	.13	.00	.24	.16	.69
L4TD – time difference, lap 4	.75	.30	-.62	.17	.05	.40	.17	.72
Factor of accuracy of the 1st shooting and the 1st lap time								
S1MS – missed shots, shooting 1	.22	.25	-.15	.93	.07	.14	.28	.88
L1TT – total time, lap 1	.59	.44	-.33	.89	.16	.28	.32	.94
Factor of accuracy of the 2nd shooting and the 2nd lap time								
S2MS – missed shots, shooting 2	.28	.24	-.21	.16	.89	.23	.21	.84
L2TT – total time, lap 2	.68	.45	-.38	.26	.78	.32	.29	.93
Factor of accuracy of the 4th shooting and the 4th lap time								
S4MS – missed shots, shooting 4	.26	.11	-.07	.14	.12	.97	.24	.96
L4TT – total time, lap 4	.71	.38	-.29	.26	.22	.87	.36	.97
Factor of accuracy of the 3rd shooting and the 3rd lap time								
S3MS – missed shots, shooting 3	.33	.10	-.18	.24	.12	.29	.97	.94
L3TT – total time, lap 3	.73	.36	-.36	.35	.18	.34	.84	.98
TMS – total number of missed shots	.43	.28	-.25	.56	.49	.66	.67	.99
Lambda	15.83	3.90	2.41	1.91	1.62	1.27	1.10	
% of variance	51.09	12.59	7.79	6.18	5.23	4.09	3.56	

Note. F – factor, Com. – communalities

Table 4. Component correlation matrix

	F 1	F 2	F 3	F 4	F 5	F 6	F 7
F 1	1.00						
F 2	.44**	1.00					
F 3	-.46**	-.21*	1.00				
F 4	.27**	.30**	-.17	1.00			
F 5	.19*	.19*	-.07	.02	1.00		
F 6	.32**	.10	-.12	.13	.14	1.00	
F 7	.29**	.08	-.13	.25**	.07	.26**	1.00

Note. *p<.05; **p<.01

Table 5. Relationship between the essential system of competition variables with the dependent variable

Variables		B	BETA	T	Sig T
TCT – total cross-country skiing time		1.00	.615	12131.957	.000
TTD – total time difference		.00	.009	.096	.923
TRT – total range time		1.00	.075	1718.953	.000
TMS – total number of missed shots		59.996	.484	13192.969	.000
Mult R	1.000				
R square	1.000				
F	250614128.017				
Sig F	.000				

Note. B – non-standardised regression coefficient, BETA – standardised coefficients of partial regression, T – value of t-test as an assessment of the statistical significance of regression coefficients, Sig T – statistical significance of standardised regression coefficients (BETA), Mult R – multiple correlation between the predictor variables and criterion variable (TT), R square – determination coefficient, F – F value, Sig F – statistical significance of the correlation between the system of predictor variables with the criterion.

rion (r = 0.90, p=.000). Also, cross-country skiing times achieved in individual laps have similarly high correlation with the criterion. The regression analysis conducted in our study showed that total cross-country skiing time can explain 55% of competitive performance of the analysed race. Luchsinger, Kocbach, Ettema, and Sandbakk (2018b) showed that during distance competitions, shooting accuracy and skiing speed relate to approximately 50% each of total performance.

According to Luchsinger et al. (2018a), about 35% of total competitive performance in a sprint competition is linked to shooting performance, and this value can increase up to 50% in individual competitions where a missed shot means one minute of added time. In our study, shooting performance accounted for 39.5% of competitive performance. Biathlon shooting is a complex task that is affected not only by factors such as physical load before shooting, time pressure, other competitors, and the necessity for fine motor control, but also by psychological and, especially, psychophysiological factors (Laaksonen, Finkenzeller, Holmberg, & Sattlecker, 2018b). Shooting performance is the result of several factors associated with the shooting technique. In a prone position, elite biathletes differ from other competitors in triggering and rifle sway, and the latter is also an important performance determinant in the standing position (Sattlecker, Buchecker, Gressenbauer, Müller, & Lindinger, 2016). During shooting in a standing position, the stability of the rifle had a strong correlation with the clearing of targets (Groslambert, Candau, Hoffman, Bardy, & Rouillon, 1999) and clearly discriminates between high and low performance shooters (Sattlecker, et al., 2016). A correlation between rifle sway and body sway was discovered (Ihalainen, et al., 2018), but is less expressed in top performers (Niinimaa & McAvoy, 1983) and clearly differentiates elite shooters from other biathletes (Groslambert, et al., 1999). At the Sochi Olympic Games in 2014, the average shooting accuracy for all individual male and female medallists was 97%. Under the more difficult wind conditions encountered at the 2018 Olympic Games in Pyeongchang, the corresponding values were 93% and 95%, respectively (Laaksonen, et al., 2018a).

Biathletes who were more successful in this individual competition also left the shooting range faster (r = 0.66, p=.000). It is very stressful to have to prepare for the shooting, fire five shots, and leave the shooting range in 25 to 30 seconds. Range time and shooting time show very little difference in elite biathletes, and therefore only account for a minor 2 to 4% of competitive performance (Luchsinger, et al., 2018a; Skattebo, & Losnegard, 2018). In our study, 5% of competitive performance was explained by total range time. Biathletes who were more successful in this individual competition were also faster shooters (r = 0.55, p=.000). The average shooting time for the 10 best male biathletes in the 20 km individual competition was 27.9 s at the World Championships in 2017 (Laaksonen, et al., 2018b) vs. 33.5 s in 1997 (Pustovrh, Jošt, & Vodičar, 1999).

As regards the interrelation of independent variables, the following findings were made. As part of our research, it was found that biathletes who were faster on the skiing track also hit more shots on the shooting range. The correlation between the variables (TCT: TMS) was r = 0.50, p=.000.

More accurate shooters fire their shots more quickly, but the shooting speed has a relatively low impact on shooting accuracy (r = 0.35, p=.000). After stopping at the shooting range, biathletes assume their shooting position and fire their first shot within 15 seconds, while the entire series of five shots normally takes about 10 seconds. During this time, the heart rate normally drops from about 90% to 60% or 70% of HRmax, during prone and standing shooting (Hoffman, & Street, 1992). Biathletes who are fast shooters in a prone position are not necessarily very fast when shooting standing, and vice versa. These correlations ranged from r = 0.39, p=.000 to 0.53, p=.000.

The times at the shooting range for shooting in prone position (L1RT: L3RT) are relatively highly correlated (r = 0.76, p=.000) as are times at the shooting range for shooting in standing positions (L2RT: L4RT – r = 0.74, p=.000). The time correlations on the shooting range, where different shooting positions are performed, ranged from r = 0.54, p=.000 to r = 0.64, p=.000. The competitors who spent less time at the range during prone shooting were also faster in the standing shooting.

Logically, faster shooters spend less time in the shooting range zone (r = 0.97, p=.000), since shooting time is a part of range time. It can be assumed that there are minimum time differences between the competitors in the distance (zone) of 10 m before the shooting range to the laying off the poles on the ground, and on the distance (zone) from the point of picking up the poles to reaching the 10 m mark after the shooting range.

A factor analysis determined seven factors which logically complete the competition outcome in a biathlon individual race – factor 1: cross-country skiing performance, factor 2: shooting time and range time, factor 3: time difference, factor 4: missed shots in shooting 1 and total time in lap 1, factor 5: missed shots in shooting 2 and total time in lap 2, factor 6: missed shots in shooting 4 and total time in lap 4, and factor 7: missed shots in shooting 3 and total time in lap 3.

The findings of our study confirm the statements Luchsinger et al. (2018b) that shooting efficiency explains a higher share of competitive performance in individual competitions (up to 50% of competitive performance) than in sprint competitions. Nevertheless, it needs to be considered that there are no poor shooters among elite biathletes, namely, the shooting accuracy of elite biathletes under normal weather conditions is above 95%. Laaksonen et al. (2018a) state that if a biathlete hopes to win an Olympic medal under normal weather conditions, he/she cannot incur more than one penalty in connection with the four shootings in the individual events. The average shooting success of medal winners in the three Olympic Games (2010–2018) was 96.1% and at the three World Championships (2016, 2017, and 2019) it was 97.2%. The contestants won medals with zero or one missed shots, and only the fastest biathletes of the last period (O. E. Bjørndalen, M. Fourcade, J. T. Bø) still managed to win a medal with two missed shots.

Regarding our research, the following limitations of the study can be mentioned. Data collected from several World Championships (or Olympic Games or World Cup competitions) would provide greater statistical power and generalisation. It would be necessary to conduct such research in other biathlon competition disciplines (e.g., group start competition, pursuit competition, etc.) and to include women's competitions in the research. In this way, we would get more detailed insight into the structure of competitive disciplines in biathlon.

The results of our research confirm the statements of the authors (Luchsinger, et al., 2018b) that shooting performance explains a higher share of overall competition performance in the individual 20 km competition than in the sprint competition. For the process of training in biathlon, this means that in the 20 km competition, biathletes who are not among the fastest in cross-country skiing can look for their chance to improve their performance (or even for the top ranking). This statement is confirmed by the results of the individual 20 km competition at the 2022 Olympic Games in China. In this competition, Belarus A. Smolski won a silver medal without a missed shot (he was 19th in the overall standings of the World Cup in the 2021/22 season), while the first-placed (Q. A. Maillet) and third-placed competitor (J. T. Boe), both evidently the fastest skiers among the biathletes, missed two shots each. Knowing the very structure of individual disciplines in biathlon can thus help coaches to more systematically direct the coaching process of individual competitors. This means that an individualised training plan has to be prepared for each biathlete with the aims to, first, optimise the athlete's relevant physiological capacity and skating technique of cross-country skiing and, second, improve and retain high shooting efficiency within the short shooting interval.

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Submitted: December 19, 2019
Accepted: January 11, 2022
Published Online First: June 10, 2022

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