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Original Article

Influence of laterality and eye dominance on successful shooting in a biathlon

MARTIN NOSEK[1], LUCIE HURDÁLKOVÁ[2], DAVID CIHLÁŘ[3]
[1,3]Department of Physical Education and Sport, Jan Evangelista Purkyně University in Ústí nad Labem, CZECH REPUBLIC
[2]Biathlon club Rover in Prague, CZECH REPUBLIC

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Abstract
The study discusses whether successful shooting in biathlon is influenced by laterality of high school students with sports background who are focusing on biathlon. To obtain the results, we used a laterality test and an eye dominance test from Unifittest 6-60 (T-116 test). At the same time, we analyzed the percentage of successful shooting in each race during the Czech Cup. The study included 37 students from different high schools who were focusing on biathlon. Values of $p<0.05$ were selected as significant. According to our findings, the results appear to be not statistically significant. The preference for upper limb or eye dominance did not indicate any effect on successful shooting by high schools students, who were focusing on biathlon.
Key words – unilateral, cross lateral, shooting, success

Introduction

Biathlon performance depends on two disciplines: cross-country skiing and shooting from a small-bore rifle. Cross-country skiing is influenced by physical abilities and by technical performance. The second important factor for being successful in biathlon is to be a great small-bore rifle shooter, which is affected by many factors.

It is known that 95% of competitors in the World Cup in biathlon prefer their right eye and right side of their body for shooting (IBU, 2017). In addition, it has been proven that an important condition for being successful in shooting in biathlon is to have an excellent eye distinguishing ability (Hoffman, Gilson, Westenburg, & Spencer, 1992; Vítek, 2009). It is known that the basic ability to shoot is influenced by the correct activation of sensorimotor pathways that influence shooting accuracy via eye-hand coordination and upper limb preference while shooting. In addition, there is also a question of whether successful shooting is influenced by laterality or eye domination of the competitor?

Laterality (from Latin latus, lateris) is defined as the relationship of right and left side of our organism or differences between paired organs. This relationship is manifested by the shape or functional differences of organs and by different activity, efficiency or specialization of one of the paired organs towards another one (Laborde, Dosseville, Leconte, & Margas, 2009). It can be said that laterality dominance originates in dominant brain hemisphere but the function of leading organ is conditional by higher functional quality of the other hemisphere. Our brain has developmentally younger functions that are located only on one side. This is the reason why they influence ability to work, motor function of hands and speech (Juračková, 2013; Payne & Isaacs, 2002).

In life, we divide particular manifestations of laterality into laterality of upper limb, lower limb, eyes and ears (Bílková, 2008; Suttle, & Alexander, 2008). Another division of laterality is shape (morphological) and functional laterality. Morphological laterality is focused on build of our body, differences in shapes, size and volume of paired organs. However, functional laterality discusses differences in motor efficiency (of upper and lower limbs) and sensory (of eyes and ears) character. We are not able to separate these two types from each other because shape and function are very close to each other.

Another division in influence on dominance is according to rate of distinction. The examples are distinctive and strong right-handedness, less distinctive right-handedness, ambidextrous, less distinctive left-handedness, distinctive and strong left-handedness (Bílková, 2008).

One viewpoint is also the relationship between upper limb laterality and eye dominance. This relationship is divided into identical laterality (the leading hand and eye are the same – right/left dominance), indefinite laterality (the leading hand, eye or both are not distinctive) and cross laterality (the leading hand and eye have different laterality) (Payne & Isaacs, 2002).

It is known that quality of movement, in terms of finer and better coordination and accuracy of its performance, depends on laterality of preference limb. However, the connection between movement using preferable or unpreferable limbs does not have to be unequivocal for everybody (Deborah, 2009). Everything is

Corresponding Author MARTIN NOSEK, E-mail: martin.nosek@ujep.cz

individual. Each person may have a different level of laterality and certain laterality preferences that may affect rate of performance similarity of preferable or unpreferable limb in certain movements (Vaverka, 2011).

As mentioned above, laterality is closely connected with eye dominance. Eye dominance has three main categories. The first on is called sensorics, when a person gives priority to one eye over the other. There may be differences between intensity of colors or brightness. The second category is directional, when a person gives preference to the eye that is concentrated on a certain subject. It can be recognized by binocular vision, and it is called the guiding eye. The last category is called oculomotor. A person prefers one eye for central fixation with binocular vision such as during rifle shooting (Zirmová, 2014). There does not have to be eye dominance for the same eye for all three categories. Dominance may differ according to scale. One eye may be strongly dominant, or both eyes may be equally dominant. In addition, it is possible that dominance alternates between both eyes (Griffiths, 2003).

It has been proven that the knowledge of laterality pattern (dominance of eye, hand and foot) makes it possible to advise situations for the more efficient adaptation of learning skills, to distinguish and guide young talents, to develop the work of limbs for each side of the body and to achieve better coordination (Laborde, Dosseville, Leconte, & Margas, 2009). Visual information is decisive for the performance of sports skills. If the visual system does not receive messages accurately or quickly enough, performance may be influence by it. It is important that visual systems function at advanced levels because sports performance may be one of the most important activities for the visual system (Deborah, 2009). The dominant eye will focus directly on external stimulus, for example an oncoming ball or a moving opponent. This suggests that the dominant eye should play a significant role in the development of sports skills such as aiming tasks in archery and golf or in faster-paced sports such as tennis and soccer (Steinberg & Parker, 1999).

Shooting sports seem to be connected through the relationship between upper limb preference and eye dominance, which significantly affect sports performance. As an example, Jones, Classe, Hester and Harris (1996) determined that learning how to shoot is affected by eye dominance. It is known that competitors who shoot using right side and have dominant left eye, or who shoot using left hand and have dominant right eye, have more trouble shooting than competitors whose dominance of eye and hand are on the same side. A similar topic was mentioned by Laborde, Dosseville, Leconte and Margas (2009). They were more focused on the effect of crossed laterality of archers. Archers are more concentrated on accuracy, whereas biathlonists are focused on speed. In addition, they registered a relationship between accuracy in archery and uncrossed hand preference and eye dominance (Laborde, Dosseville, Leconte, & Margas, 2009). They came up with interesting findings, which require another study. They determined that the most experienced archers with uncrossed laterality use the more dominant side in archery than in ordinary life, and the most experienced archers with crossed laterality use their dominant side less than in ordinary life.

The results of studies by Jones, Classe, Hester, & Harris (1996) and Vaverka (2011) suggest that laterality of the upper limb preference is one of the most important factors that influence accuracy of simple movements. In addition, from the point of view of laterality, it demonstrates that limb preference affects accuracy for increasing load.

There is another fact about interaction between eye-hand dominance on other sports skills. In term of tasks that characterize duel sports, the dominant eye is requested and is functionally connected via the lateral geniculate nucleus to the ipsilateral hemisphere. By contrast, if we are talking about manual responses, the responding hand is connected to the contralateral hemisphere via its motor area. Therefore, the functional connection between visual input and motor output involves only one hemisphere for subjects with a contralateral relationship between the dominant eye and the responding hand. Therefore, these subjects do not need this interhemispheric transfer. The advantage in reaction times is the result of them compared with subjects with ipsilateral dominant eye and responding hand (Azémar et al., 2008; Balkó, 2016; Balkó, Borysiuk, Balkó, & Špulák, 2016). At the same time, the results prove that reaction time of elite and amateur athletes is the same (Balkó, Borysiuk, & Šimonek, 2017; Balkó, Wasik, Chytrý, Dunajová, & Škopek, 2017).

Nevertheless, these studies are exceptions, and many studies failed to find any link between eye dominance and upper limb perforation. As an example, we can consider studies on baseball (Classe, Daum, & Semes, 1996) or cricket players (Thomas, Harden & Rogers, 2005). The origin of dissimilar results of eye and hand dominance relating to better sports achievement can be connected with the correct use of the test to recognize dominant position of observation, which enables diagnosis of central dominance. However, it is true that observation of dominant position is somehow connected to sports levels. The practical findings show that it is hard to define uncrossed and crossed dominance.

At the same time, it is important to say that shooting from a small-bore rifle in biathlon is diametrically different form a hit in baseball or in cricket. It has been proven that the uncrossed laterality of eye-hand is distinctly more successful than of the crossed eye-hand, given the aspects of activity, motion-less target, and nonexistent time pressure. Furthermore, to aim at the target, athletes must adjust two points between the eye and the target. Thus, it is an advantage to use the arm that corresponds with the sighting eye (unilateral eye-hand dominance) (Deborah, 2009).

In conclusion, the determination of dominant eye in target sports is important and can have a significant effect on successful shooting. Biathlon is one of these sports. However, until now, no one has conducted a study on issues of laterality or eye dominance.

This study is focused on evaluation of leading eye and upper limb laterality in 15-19-year-old high school students with biathlon major and on comparison of their successful shooting reliance with the results of standardized test of laterality and eye dominance. This field has not been sufficiently researched. The aim of this study is to evaluate connections between eye dominance and laterality of upper limb with shooting success or failure.

Materials and methods

Participants

The research group consisted of 37 high school students, who are focusing on biathlon (16.4 ±1.24 years of age) from Nove Mesto, Jablonec and Jilemnice, Czech Republic. The average time of biathlon practice of each participant was 4.87 years. It included practice shooting from air gun and from a small-bore rifle. The research project was also approved by the Ethics Committee on April 14, 2016 under the reference number 1/2016/06.

Methods

The main method that was used for this research was the method of observation. This method was used for examining laterality using the T-116 test (Matějček, 2007). The T-116 test determines laterality preference and hand and eye dominance in children and adults. The test consists of 10 tasks for the upper limb, such as putting beads in a bottle, clicking pins into gaps, inserting key into a lock, throwing ball into a box, pressing a solid box, pressing the examiner's hand down, and touching ears. The T-116 test includes two additional tasks that are focused on eye dominance and involve looking through a manuscope and ocular (Matějček, 2007).

The second method that we used was the method of interrogation. Interrogation was used to determine certain information: age, experience with shooting, which eye and hand the participants use when they shoot.

The last method that we used was analysis of documents, which was used for analysis of shooting results from 8 competitions of the Czech Cup in biathlon in 2017 (Czech biathlon union, 2017).

Procedure

The participants were divided into 5 groups according to their laterality, which was determined using the T-116 test. The following groups were created: R: distinctive right-handedness, R*: less distinctive right-handedness, A: ambidextrous, L*: less distinctive left-handedness, L: distinctive left-handedness. The focus was put on percentage of successful shooting. Then, the students were divided according to right eye dominance and left eye dominance. Again, the focus was on successful shooting. The last procedure was a complex analysis where the participants were divided into groups in relation to eye dominance and gun position. We created three groups: unilaterality (identical dominant eye and gun position), crossed laterality (opposite dominant eye and gun position) and indeterminate laterality (no distinctiveness between leading hand, eye or both). Based on these groups, we were trying to identify a connection with successful shooting.

Statistical analysis

The results of the laterality, eye dominance and successful shooting were processed using the Statistica software (StatSoft Inc., 2016). The Shapiro-Wilks test confirmed that the data were not normally distributed. Therefore, nonparametric statistical methods were used. To identify a dependence between each shooting round in biathlon, we used the correlation coefficient (Spearman Rank Order Correlations). To analyze the relation between laterality, eye dominance and successful shooting of multiple groups, the Kruskal-Wallis ANOVA test was applied. The Mann Whitney test was used to evaluate the relations between eye dominance and successful shooting, where the groups were divided according to eye dominance. The statistical significance was set to $p<0.05$. In addition, the effect size was counted.

Results

Shooting success

The analysis of shooting success includes 8 competitions from the Czech Cup in biathlon in 2017. For our analysis, we used 28 shooting rounds (14 prone position, 14 standing position) for each participant. The findings for the entire group of participants are as follows: the shooting success at prone position is 69.43%, at standing position it is 59.08%, and the total is 64.63%. If we look at the mutual relation between each shooting round, there is a significant correlation dependence. High shooting success at one shooting round predicts high shooting success at other rounds as well as the total shooting success ($r= 0.58\sim0.9$; $p= 0.000\sim0.0001$). Table 1 presents the results.

Table 1. Shooting success

Shooting round	N	r	t(N-2)	*p*
Prone × Standing	37	0.588697	4.30848	**0.000127*
Prone × Total	37	0.860411	9.98870	**0.000000*
Standing × Total	37	0.901531	12.32578	**0.000000*

p<0.05

Laterality of upper limb and shooting success

Based on the tests during our research, we detected 24 participants with distinctive right-handedness, 6 with less distinctive right-handedness, 2 ambidextrous participants, 1 with less distinctive left-handedness and 4 with distinctive left-handedness. As demonstrated below (Table 2), the best results in prone position were recorded for the group with distinctive left-handedness (74.16%), the worst score was recorded for the group with less distinctive right-handedness (65.94 %). The best results for standing position were presented by the ambidextrous group (63.33%). However, the worst shooting success was presented by students with less distinctive left-handedness (36%). The best total shooting success was exhibited by the ambidextrous group (67.08%). The worst results were demonstrated by a less distinctive left-handedness student (53%). Total shooting success was analyzed for 8 biathlon competitions in the Czech Cup.

Table 2. Laterality of upper limb and shooting success

Laterality of upper limb	N	Shooting success Prone			Shooting success Standing			Total shooting success		
		(%)	Med.	SD	(%)	Med.	SD	(%)	Med.	SD
R	24	69.37	69.16	15.1	61.2	62.5	15.37	65.67	67.25	13.89
R*	6	65.94	69.16	15.64	52.59	49.16	13.07	60.04	59.16	12.65
A	2	70.83	70.83	3.53	63.33	63.33	16.49	67.08	67.08	10.01
L*	1	70.00	-	-	36.0	-	-	53.0	-	-
L	4	74.16	77.5	8.66	59.72	58.33	7.71	66.94	67.91	7.64

Explanatory note: R: distinctive right-handedness, R: less distinctive right-handedness, A: ambidextrous, L*: less distinctive left-handedness, L: distinctive left-handedness*

The Kruskal-Wallis ANOVA test was used to analyze the dependence of laterality and shooting success. The right-handedness and left-handedness categories were reduced because of low number of participants in each category. There is still a category of ambidextrous participants. The analysis did not confirm any dependence of preferred upper limb on shooting success in each shooting round (p=0.746~0.908). The results are demonstrated in Table 3.

Table 3. Dependence of upper limb on successful shooting

Prone position			
Laterality	N	Med.	*p*
Right	30	69.16	
Ambidextrous	2	70.83	*0.896*
Left	5	75.00	
Standing position			
Laterality	N	Med.	*p*
Right	30	61.66	
Ambidextrous	2	63.33	*0.746*
Left	5	64.16	
Total shooting			
Laterality	N	Med.	*p*
Right	30	67.00	
Ambidextrous	2	53.33	*0.908*
Left	5	64.16	

p<0.05

Eye dominance and shooting success

Table 4 illustrates the results according to the eye dominance of the participants. There were more students with right eye dominance (23) than with left eye dominance (14). The results demonstrated below are balanced. Specifically, there is no significant relation between successful shooting and eye dominance (p=0.668~0.907).

Table 4. Eye dominance and shooting success

Eye dominance	N	Shooting success Prone		Shooting success Standing		Total shooting success	
	(%)	(%)	Med.	(%)	Med.	(%)	Med.
Right	23 (62%)	68.38	62.51	59.81	61.47	65,32	64,54
Left	14(38%)	69.78	69.16	58.64	57.89	64,21	62,04
p		*0.907*		*0.668*		*0.755*	

p<0.05

Dependence of laterality, eye dominance and gun position on successful shooting

The main goal of this research was to determine whether gun position, eye dominance or upper limb laterality influence the shooting success in biathlon. To test this specific dependency, we divided participants into 3 groups. The groups were created according to a relation between laterality and gun position of unilaterality, crossed laterality and indeterminate laterality. For the evaluation of results, we used the Kruskal-Wallis ANOVA test. As shown in Table 5, we reject the influence of laterality, eye dominance and gun position on successful shooting (p=0.453).

Table 5. Relations between upper limb laterality, eye dominance and successful shooting

	Shooting success			
Laterality (eye-hand dominance)	Prone (%)	Standing (%)	Total (%)	*p*
Unilateral	69.52	59.32	64.51	
Cross lateral	68.94	58.04	64.47	*0.453*
Indeterminate laterality	70.83	63.33	67.09	

p<0.05

Discussion

In the presented research, first, we focused on shooting success. According to the abovementioned results, we determined that participants were successful in 69.43% of the time in prone position, in 59.08% in standing position, and the total success was 64.63%. It is clear that there were more unsuccessful shooting participants than successful shooters. This may be because most of the participants were first year high school students and were not very familiar with rifle shooting.

In our results, standing position demonstrated lower shooting success. This may be caused by juveniles with insufficient experience with shooting in standing position (younger categories only shoot in prone position). The more experienced the participants are the more successful they are. Those who were successful with shooting in standing position were upper-grade high school students. However, this is not a condition. Knapp (2011) states that young biathlonists should focus on the shooting technique from the beginning, and then the perfect technique will help them with their shooting performance. The beginner athletes, who were practicing according to his methodology, have never struggled with improving their performance, and they did not experience negative influence on their technique. The athletes, who did not train using Knapp´s methodology, had certain errors in their shooting technique (holding of the gun, shooting posture, etc.). According to Straňák (2007), stability is also one of the main factors of successful shooting. He proves it in his research, where the athletes with great stability were successful in shooting in 80% of the time, and those with poor stability were only successful in 40-50% of shooting attempts. If we apply this factor to our research, we can see that the best achievement was 90% of successful shooting in prone position, and the worst achievement was 40% of success. It will be interesting to evaluate this fact in more detail to determine if it is related to stability factor. It is also confirmed by Hoffman, Gilson, Westenburg and Spencer (1992) who said that physical load during the same intensity does not influence shooting in prone position as much as in standing position. Shooting in standing position is more difficult for biathlonists due to the following aspects: worse posture stability, gun holding and shooting technique. In standing position, center of gravity is higher than in prone position, and there is minimum support for the rifle. Therefore, the targets are bigger than those for the prone position shooting.

Second, we focused on shooting technique. We wanted to know whether low shooting success was also influenced by something other than stability. Therefore, our research was focused on laterality and eye dominance factors in relation to shooting success. The findings show that the most successful group in prone position shooting was the distinctive left-handedness group. The most successful group in standing position and in total shooting success was the ambidextrous group. The topic of distinctive left-handedness and ambidextrousness was studied by Healeye (2002). It is known, that people with distinctive left-handedness and ambidextrousness have better orientation in space than people with distinctive right-handedness. The orientation in space is advantage for sports with target shooting such as biathlon. It is important to add that if a left-handed individual uses a gun that is designed for right-handed people, the individual may lose his/her advantage.

The values in our research are similar. This demonstrates that eye dominance or laterality do not have any effect on successful shooting. Therefore, we agree with Veverka´s (2011) study that there may be a certain influence of laterality, but there is no clear explanation. His opinion led us to perform complex analysis where we put our focus on relations between shooting success and eye dominance and upper limb preference. The best results in all categories (prone and standing positions, as well as in total) were reached by the indeterminate laterality group, and the worst results were presented by the group of participants with crossed laterality. People with indeterminate laterality are able to use both hands, and they do not have any preference as to which hand they use. There are connections between other researches, such as Jones, Classe, Hester and Harris (1996) and Laborde, Dosseville, Leconte and Margas (2009), who recorded higher percentage for the indeterminate laterality group of people in shooting compared with the crossed laterality group. The results are comparable with the studies by Razeghi, Shafia, Shebab and Maleki (2012) or Dalton, Guillon and Naroo (2015). The decisive difference is that these studies were performed in golf and cricket, where both eyes are used for hitting the ball. Instead, data shows that the concept of eye dominance is fluid because the dominant eye shows regional differences (that is, dominance depends on location in the visual field) and appears to be highly dependent on additional factors such as gaze direction and the hand being used (Barrett, 2016).

We are aware of other factors that influence shooting performance of athletes. Laterality and eye dominance are some of the factors that visibly influence coordination of biathlonists while shooting. According to Ondráček (2011), the final performance is affected by other factors such as emotional state of biathlonists, pulse, breathing frequency and shooting technique.

Conclusion

Even though, the results did not confirm any significant relations between laterality, eye dominance and shooting success, we are convinced that crossed laterality in relations with eye dominance/laterality of gun position, where the person must use his/her not preferred arm for shooting, has negative impact on successful shooting, coordination and fine motor skills. It will be interesting to observe what happens to beginners in biathlon who focus on laterality and eye dominance and to determine whether there is a positive impact on their performance throughout the years.

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