IBU RESEARCH GRANT PROGRAMME

Final Research Report

Project title:

The influence of balance and mindfulness training on shooting performance in young biathletes

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Period: 19 November – 31 July

Date of the presentation to the IBU: 30 June

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1. Abstract

The aim of the project was to evaluate the effectiveness of two alternative approaches to improving shooting performance in biathletes. The first is based on motor competence and focuses on body balance. An effective postural balance not only reduces the risk of bodily imbalance, falls or subsequent injuries, but also contributes to the optimization of motor performance in a number of sports. The second approach focuses on psychological competence and is based on the concept of mindfulness. Mindfulness is a way of paying attention that involves intentionally being aware in the present moment and accepting things as they are, without judgment. Recent findings indicate that aspects of mindfulness are positively linked to better shooting performance at competitions, which is associated with higher levels of awareness and refocus. Therefore, with the 6-week balance training program and 6-week Mindfulness Sports Performance Enhancement (MSPE) program, both implemented in parallel in youth biathlon competitors, we aimed to improve the shooting performance of the biathletes and verify effectiveness of these programs. The research was conducted on a group of 16 youth biathletes being an experimental group and 10 youth biathletes being the control group. Both groups were included in the National Sports Championship School program. The study was implemented during the competitive season. The measurements encompassed functional balance measurements, balance measurements on force platforms, dry shooting measurements using the Scatt shooting system and a battery of psychological inventories and tests. Additionally, the aiming characteristics were evaluated with the use of video tracking system with the laser feedback trials. The performance of the biathletes was also verified in the fatigue condition after a short intensive effort on the ski ergometer. The experimental group was divided into a Stability (n=8) and Mindfulness group (n=8), and after the baseline measurements, they have realized different training programs in parallel additionally to their regular practice.

There were significant correlations between the posturographic characteristics and shooting performance. There were also significant correlations between shooting performance and the results of Mindfulness test and inventories. After the training, these dependencies were even more emphasized than before the training. The trials after effort that was implemented in the experiment did not change these characteristics significantly. As far as the improvements in the balance and Mindfulness are concerned, we were only able to observe a positive tendency in the direction of improvement, however these changes were not statistically significant.

The most important finding of the research and its potential value is the confirmation of the hypothesis that the body balance and the level of mindfulness can significantly contribute to the shooting accuracy. Future studies should use the employed methodology in more advanced athlete and larger population to confirm our results. It could be possible that the outcomes of the study could be more visible if the training program was implemented at the beginning of the preparatory period.

Key words: postural balance, mindfulness training, shooting performance, training, core stability, functional training

2. Executive summary

The project focuses on the evaluation of effectiveness of two alternative approaches to performance enhancement of biathletes. First is based on motor competence and is focused on postural balance and the second approach focuses on psychological competency and is built on the concept of mindfulness. Recent research suggests that in resting conditions and after physical exercise, rifle sway during aiming at the target in a standing shooting position seems to be coordinated with the postural sway of the biathlete's body. Thus, an increase in postural sway contributes to a greater sway and lesser stability of the rifle. With respect to the second approach, the core of mindfulness is a way of paying attention that entails intentionally being aware of the present moment and accepting things just as they are without judgment. Mindfulness-based approaches in sport, exercise, and performance psychology is a fast developing area of sport psychology. There are many athletes (and coaches) who know that mental factors such as concentrating, relaxing, and letting go of thoughts and feelings can aid performance, but have no idea how to actually do these things under the pressures of training and competition. Moreover, recent findings indicated that mindfulness facets were positively associated with shooting performance, with higher levels of Awareness, Refocusing, and Non-judgmental being related to better shooting performance in competitions. The 6-week balance training program and a 6-week Mindfulness Sports Performance Enhancement (MSPE) program was implemented in parallel among youth biathlon athletes in order to elicit improvements in their performance and verify the effectiveness of these programs.

The main and intermediate objectives of the project are:

1. Implementation of a specially designed balance training for a group of biathletes into their regular practice. This program is focused on strengthening central stability and improving functional stability. As a result of this intervention, we expect a reduction in the swaying of the posture, better control over the rifle, which is followed by better results in shooting.
2. Implementation of the Mindfulness Sports Performance Enhancement (MSPE) program into the regular practice of biathletes. Its effects should be visible in the individual execution of shooting.
3. Objective evaluation of the effects of training programs using recognized methods of biomechanics performance analysis and validated psychological tests.
4. Identify the best indicators of high performance in shooting. The analysis of the results of the competition and the results of research will be carried out in parallel and consolidated.

5. Assessment of the potential value of the programs used for training practice and sports success.
6. Advanced analysis of balance results to find their correlation with sports performance.

The study was conducted on sixteen youth biathlon competitors which was randomly divided into two groups (Stability and Mindfulness), which began in parallel two different training programs in accordance with the assumptions of the project proposal. Additionally, ten biathlon competitors were recruited for the control group which did not realize any additional training during the time of the study.

Measurements

The measurements consisted of several procedures with the use of different equipment. First the functional balance and stability was assessed with the use Y Balance test™ kit. Further, for standard and functional balance evaluation, a force platform was used (AMTI OR 6-7). Next, the balance measurements in shooting position with a rifle (standing on a force platform, AMTI BP600900) in different conditions were conducted – with a laser feedback and without. The participants have also undergone the fatiguing protocol, which consisted of performing an exercise with the use of SkiErg Ergometer. Immediately after the fatiguing protocol they were asked to step on the force plate and execute another series of dry shooting to the Scatt biathlon shooting target or aiming to the target with a laser feedback. During the trials with the laser feedback a HD video camera was used to register the trajectory of aiming that was projected to the shooting target. The trajectories were further traced in the video Tracker software and processed in Matlab. The measurement procedure also encompassed the set of the psychomotor test and psychological inventories. These were: Choice Reaction Time test (*CHORT), Mindfulness Inventory in Sports, Sport Anxiety Scale-2 (SAS-2)* was used, *Sport Mental Toughness Questionnaire (SMTQ-P),* and Trait Sport-Confidence Inventory (TSCI). The raw platform data and tracked laser trajectories were further processed and analyzed. Apart of the standard COP measures the rambling and trembling COP signal decomposition was employed to the COP data to detect more subtle changes in postural control.

Results

There were significant correlations between the posturographic characteristics and shooting performance. There were also significant correlations between the results of Mindfulness test and inventories. After the training, these dependencies were even more accentuated than before. We also wanted to show some additional

As far as the improvements in the balance and Mindfulness are concerned we were only able to observe a tendency in the direction of improvement, however these changes were not statistically significant.

There were no significant changes in the functional balance estimated with the use of the YBT except for the Control group. The control group presented significantly

lower scores in comparison to the experimental group and had higher potential for improvement.

The tracked laser data (stability of the rifle while aiming) was especially interesting in the fatigue condition. After the training, we have discovered different tendencies of changes in this signal between the groups. The “Stability” group presented lower scores in most parameters suggesting more focused aiming trajectory. On the other hand, the “Mindfulness” group presented slightly higher values of these parameters in most cases. Unfortunately, these differences were not statistically significant and one can only suggest some tendencies. Finally, the control group showed statistically significant different results in most cases towards the higher values, meaning that their aiming trajectory was less focused and more variable.

Conclusions

The most important finding of the research and its potential value is the confirmation of the hypothesis that the body balance and the level of mindfulness can significantly contribute to the shooting accuracy. Future studies should use the employed methodology in more advanced athletes and larger population to confirm our results. It could be possible that the outcomes of the study could be more visible if the training program was implemented at the beginning of the preparatory period.

The proposed balance training accentuated lower quarter of the body. The training was created based on the information gained from the trainers and apart from the effects that were visible in the change of the posturographic parameters, it also could elicit positive changes in the more dynamic performance like skiing. Unfortunately, this was not evaluated and only individual reports from the study participants’ confirm this hypothesis. We are now trying to find some objective methods to confirm this hypothesis in the future.

In the project the data was analyzed globally and averaged. However, it is worth to report that some individuals are more susceptible to interventions than the others. Again, the individual statements of the participants were quite positive, especially with respect to the MSPE training. They reported that they were able to cope with the stress and to refocus much better with the use of the methods they were presented within the course of the project. Although, the participants had some experience with psychological training, the MSPE was a novelty for all the participants. Currently we plan to incorporate both trainings in the control group with the use of the created database and media withing the online platform created thanks to the project.

Finally, the developed methodology concerning the tracking of the aiming trajectory brought an interesting result, however not statistically significant. Presumably, the proposed balance training has led to better control of the rifle during aiming and resulted in a more focused tracing. This should be further explored in the future

experiments. The lack of significant changes could be explained partly with the issues mentioned in the limitations of the study.

Limitation of the study

The small number of participants can be listed as one of the limitation the study, which prevent us from making broader inferences to wide population. Second, which might be considered a limitation as well as a strong point, is the study group which were young competitors. They are sometimes not that focused on the best results of the training like the senior competitors. We would expect better results with higher level of competitors. Third the project was incorporated during the ongoing competitive season. It might be possible to have better results when the program would be completed before the competition season stars. Last but not least, was the use of the Scatt shooting system for the performance analysis. Scatt, being a training system, is a decent tool for dry shooting training. However, it does not reflect the actual shooting that is executed during the competition. We believe that we could have better results when we could analyze actual shooting results from the shooting range.

3. The Report

3.1. Introduction

Performance and success in sports are dependent on both physical and psychological ability and preparation. To achieve this, athletes must successfully deal with the demands of their discipline and potential disturbances [1].

On the other hand the balance ability was also found to be substantially linked to a number of performance measures in a number of sports. Bipedal static balance while shooting was associated with shooting accuracy for elite and novice rifle shooters [2, 3]. Other factors such as rifle stability may be independent of balance and can also influence shooting accuracy [2]. Balance ability was significantly related to shooting accuracy for junior archers but not senior archers [4]. The senior archers had superior balance ability when compared with junior archers; a high level of stability is a prerequisite to becoming an elite archer and, at this level of expertise, the range of postural sway is small and was not an important discriminating factor for elite senior archers [4]. A review of the literature does not allow to draw unambiguous conclusions about the indirect impact of an athlete's level of balance on his shooting abilities. There is a particular deficit of evidence-based research in the field of biathlon.

The relative contribution of improved motor or sensory function to enhanced performance in a motor task from balance training is unknown. Proprioception is a part of the sensory system that provides information on joint position or detecting joint motion, and is a component of the balance system. Whether proprioception can really be improved by exercise has been questioned and it is speculated that athletes might just become more skilled at focusing on and attending to important sensory cues with training and producing refined motor responses. For example, gymnasts balancing on the beam may learn to pay full attention to ensure they detect all larger body segment acceleration to minimize motion and improve performance [5]

Balance training may lead to task-specific neural adaptations at the spinal and supraspinal levels. It may suppress the spinal reflex excitability, such as the muscle stretch reflex during postural tasks, which leads to less destabilizing movements [6] and improved balance as required in sports such as gymnastics and rifle shooting. The inhibition of muscle stretch reflexes may enhance agonist-antagonist muscle co-contraction, which increases joint stiffness, stabilizing the joints against perturbations and therefore may improve balance [7]. Task-specific reduced cortical excitability has also been associated with improved balance from training. It is postulated that balance training promotes a shift in movement control from cortical to sub-cortical and cerebellar structures [7].

A variety of forms of mental education may contribute to physiological and psychological performance or emerging performance. One is Psychological Skills

Training (PST), which generally refers to cognitive behavioral techniques, including goal-setting, imaging, mental repetition, control of arousal, self-talk/pre-competitive routines [8]. Mindfulness as another form of mental training has become increasingly popular among athletes. Defined by Kabat-Zinn, mindfulness is a structured mind- set to being aware of the present-moment experience in an accepting, non-judging, and non-avoiding way [9], which can be understood as a state or trait [10].

Research indicates that mindfulness is associated with a number of forms of mindfulness practice (e.g. different forms of meditation or yoga) [11] or the informal practice of mindfulness in daily life [12]. Mindfulness is thought to influence physiological and psychological states through a variety of processes, such as simple attention, experiential acceptance, non-attachment, or clarity of internal life [13]. In contrast to most forms of PST interventions that directly aim to change dysfunctional thoughts and emotions [14], interventional approaches that can be subsumed under the concept of mindfulness target altering the relationship to physiological and psychological states. The initial involvement of mindfulness in sport was reported by Kabat-Zinn et al. in rowing in the early 1980s [15]. As a result of this introduction of mindfulness in the sporting world, only a few applications of mindfulness favoring forms of meditation were applied before the turn of the century. Nevertheless, after many years of rapidly growing popularity of mindfulness in clinical psychology, an increasing interest of mindfulness-based interventions could also be observed in sports. That growing popularity led to the development of two sport-specific and documented mindfulness-based intervention programs: the Mindfulness-Acceptance and Commitment approach (MAC) [16] and the Mindfulness Sport Enhancement Program (MSPE) [17]. Both are group actions which consist of several sessions over several weeks. The Cambridge Handbook of Mindfulness and Performance [18] offers a comprehensive view of all current mindfulness interventions in sport. Additionally, Mindfulness-based Interventions (MBIs) have been found to directly affect fine motor sport performances in sports involving precision, accuracy, and dexterity [19, 20], such as shooting [21] and dart throwing [22], in addition to being linked to enhanced psychological parameters [18, 23], such as improved flow experiences, self-confidence, and competitive anxiety, in archers [24, 25]. The authors of a recent study by Wu et al. [26] investigated a mindfulness-based intervention (MBI) called mindfulness-based peak performance (MBPP) on shooting performance in archers and showed the MBPP program significantly improved the shooting performance and other cognitive functions. It is expected that a similar effect will be achieved in biathlon, which is supported by the preliminary study by Josefsson et al. [27] where they correlated the athlete's performance with their individual level of mindfulness.

Based on the recent literature and after many consultations with practitioner we have decided to verify experimentally the impact of both balance and mindfulness

training programs on the shooting performance in biathletes, which has not been done so far with an evidence based approach in biathlon.

The main objectives of the study was to show interdependence between shooting performance and balance performance as well as the Mindfulness level of athletes. We wanted to prove that the focused training in both aspects, i.e. balance and mindfulness would elicit significant, positive changes in athletes performance. We believe that the effect of this study can be easily incorporated in the regular training of the biathlon competitors at all level of expertise.

3.2. Material and methods

3.2.1. Participants

The experimental group consisted of sixteen youth biathlon competitors which was randomly divided into two groups (Stability and Mindfulness), which began in parallel two different training programs in accordance with the assumptions of the project proposal.

Ten biathlon competitors were recruited for the control group which did not realize any additional training during the time of the study. The groups characteristics were presented in table 1.

Table 1. Basic characteristics of the participants

Group	N	Age [mean±SD]	Height [mean±SD]	Weight [mean±SD]
Stability group	8	17,5 ±1,8	168,6 ±8,2	61,2 ±6,1
Mindfulness group	8	17,4 ±2,4	173,1 ±9,9	65,0 ±8,6
Control group	10	17,2 ±1,9	174,2 ±8,0	69,8 ±7,2

3.2.2. Procedures

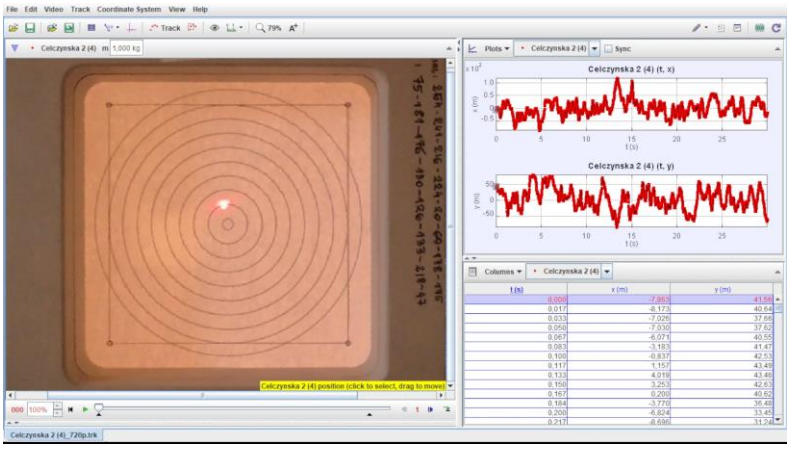
Before the start of the training phase of the project, a specialized “Balance enhancement training program dedicated to Biathlon” was developed (see annexes). It was consulted with coaches to adjust it to the special need of the discipline. The training was divided into three phases to implement the change and progression of the exercises. Two weeks have been allocated for each phase. At the beginning of each phase, instruction in performing exercises was conducted by a motor preparation specialist with the participants. The implementation and course of training was controlled by coaches and through the players' own work. In situations requiring contact, support was provided from the research team. Similarly to the Balance training, the Mindfulness training was conducted by the psychologist during the 6-week period. It encompassed six, face to face, sessions (once a week) and

personal/individual work of the participants following the recommendation of the Mindfulness Sport Performance Enhancement (MSPE) program [28].

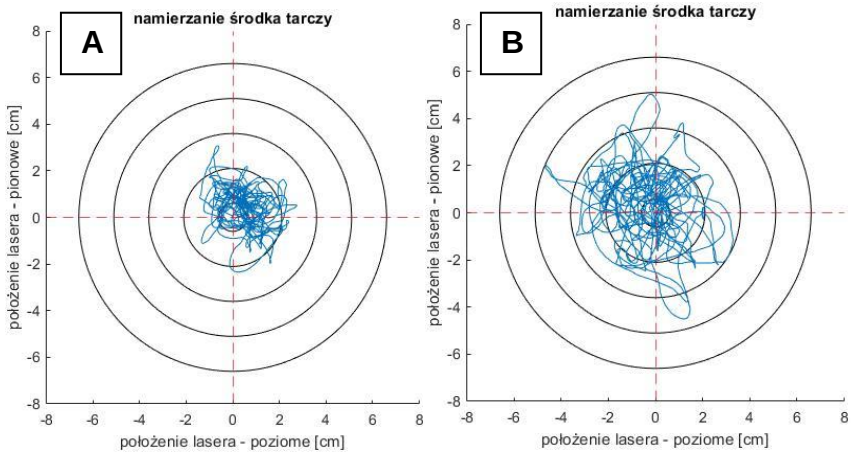
Before the beginning of the 6-week training and at the end of the training period, a series of measurements were conducted (see description below) in the experimental group. Similarly, before and after 6 weeks in the same time period, the control group, that did not carry out additional trainings, was examined.

Measurements

The measurements consisted of several procedures with the use of different equipment. First the functional balance and stability was assessed with the use Y Balance test™ kit. It is an instrumented modification of the Star Excursion Balance Test (SEBT). The test was conducted for the upper quarter and lover part of the body. The Composite Reach Distance (CRD) was the main outcome variable. Further, for standard and functional balance evaluation, a force platform was used (AMTI OR 6-7). The procedure encompassed two trial of 60 s of quiet standing and three trial of limits of stability (LOS) test. The LOS test trials lasted 30 s. The raw data (forces and moments) of these trials were registered at 100 Hz frequency. It was further processed and standard center of foot pressure (COP) measures were calculated using Matlab (path length, range, velocity, rms, standard deviation). Next, the balance measurements in shooting position with a rifle (standing on a force platform, AMTI BP600900) in different conditions were conducted. The procedure were the following: rifle aiming to a shooting target placed 5 m away from the end of the rifle barrel. The shooting target from the Scatt training system was used. First, the participants were instructed to aim to the center of the target in a standing position for 30 seconds (no feedback). Next, with the laser attached to the rifle barrel the participants were asked to aim to the center of the target with the laser feedback for 30 seconds. For the next condition biathlon shooting target as the part of the Scatt's training system was used. The participants were instructed to dry shoot the targets using the Scatt training system continuously over the 30 seconds. After completing trials in this condition, the participants have undergone the fatiguing protocol, which consisted in performing an exercise with the use of SkiErg Ergometer. They exercised with high intensity until their HR reached the 80% of their HR max. Immediately after the fatiguing protocol they were asked to step on the force plate and execute another series of dry shooting to the Scatt biathlon shooting target. Between the shooting trials the effort was repeated to sustain the fatigue. Finally, the procedure was ended with aiming to the standard shooting target with a laser feedback – but after the fatiguing protocol. Like the previous condition the fatigue was repeated before each trial. The trials in each condition were repeated three times. During the trials with the laser feedback we used HD video camera to register the trajectory of aiming that was projected to the shooting target. The trajectories were further traced in the video Tracker software (pic. 1) and processed in Matlab in order to achieve similar parameters that came from the force plate (pic 2).



Pic 1. Exemplary trajectory of the laser on the shooting target during the trial with feedback (https://physlets.org/tracker/).



Pic 2. Exemplary trajectory of the laser in Matlab **A**) before fatigue, **B**) after fatigue from the same athlete

The set of the psychomotor test and psychological inventories were conducted in parallel with the balance and shooting performance tests. First the Choice Reaction Time test (*CHORT)* was conducted, which is a psychometric test that is part of the TEST2DRIVE system. The CHORT test is a response time test with a choice. The test is designed to assess the speed and adequacy of the response in a complex situation. The test results are influenced by both the speed of reaction and the ability to inhibit abnormal reactions. Average response time is assessed using the median response time. The time of extended reactions (the variable calculated as the 90th percentile of the individual distribution of correct reaction times) is an auxiliary measure of the effectiveness of attention processes. Second the *Mindfulness Inventory in Sports.* The MIS assesses the ability to pay attention to present-moment experience in a non-judgmental way in the context of sport [29]. It consists of 15 items with three 5-item

subscales. First, it measures awareness of harmful stimuli and their associated internal reactions; second, adopting a non-judgmental attitude towards these stimuli and responses, and third refocusing attention rapidly on goal-directed cues. Next the *Sport Anxiety Scale-2 (SAS-2)* was used [30], which is a 15-item measure of how anxious athletes feel before or during competition. The measure yields a total score as well as three subscale scores (Somatic Anxiety, Worry, and Concentration Disruption). *Sport Mental Toughness Questionnaire (SMTQ-P),* which is a polish version of SMTQ [31], being used to measure mental toughness. The 13-item SMTQ-P provides a global measure of mental toughness as well as the four subscales of Self-confidence, Effectiveness, Emotional control, and Task fulfillment. Finally the Trait Sport-Confidence Inventory (TSCI) [32] was used, which composes of 13 items that measure sport specific self-confidence and assess how confident athletes generally feel, when they compete in sport.

Data processing and statistical analysis

Once the pre and post-trainings measurements were completed, the raw platform data and tracked laser trajectories were further processed and analyzed. Apart of the standard COP measures the rambling and trembling COP signal decomposition was employed to the COP data [33] to detect more subtle changes in postural control.

The following variables were further analyzed:

1. **Force plate data from quiet standing and in shooting position with a rifle in anterio-posterior (AP) and mediolateral (ML) direction:** area, range of COP (raCOP), standard deviation of COP (stdCOP), rmsCOP_AP, COP path length (lenCOP), COP velocity (vCOP), range of rambling (raRAMB), standard deviation of rambling (stdRAMB), rms of rambling (rmsRAMB), path length of rambling (lenRAMB), velocity of rambling (vRAMB), range of trembling (raTREMB), standard deviation of trembling (stdTREMB), rms of trembling (rmsTREMB), path length of trembling (lenTREMBD), velocity of trembling (vTREMB), sample entropy (sampEntr).
2. **Laser tracker data (in horizontal and vertical direction – X,Y):** range (rangX, rangy), standard deviation (std_X, std_Y), rms (rmsX,rmsY), path length (sX, `sY), velocity (vX, vY), total path length (s_total), total velocity (V_total), sample antropy (ent_X, ent_Y).
3. **:** shooting rhythm stability [%] (rhythm_stab), mean length of the aiming path [mm] (mean_S) [mm], mean horizontal length of the aiming path [mm] (mena_S_Horiz), mean vertical length of the aiming path [mm] (mena_S_Vert), shooting score number (score), index of shooting score (score_indx)
4. **Mindfulness test and inventories:** Awareness, Not judgmental, Refocussing, Worring, Distractions, Emotional Control, Confidence.
5. **CHORT test:** mean reaction time (CH_mean_rt), percent of errors (CH_%_errors), prolonged reactions (CH_long_rt).

6. **Y-Balance test Upper and Lower quarter:** Composite Reach Distance (CRD)

Standard methods of descriptive statistics were used first and data distribution was evaluated. In most cases the data was normally distributed. Therefore, the decision about the use of the parametric test was taken. For the pre and post-training comparison the Student t test was used for dependent variables. In case of multiple comparisons the ANOVAs were applied. Correlation analysis was conducted between the laser tracker software data and COP data as well as between psychological inventories. The significance level was set at $p<0,05$. All statistical calculations were conducted in the Statistica software package v. 13.3.

3.3. Results

The first step of the data analysis was a verification whether there are some significant dependencies between balance data end shooting performance. Therefore we have conducted Pearson's linear correlation between the Scatt training system data and basic COP parameters as well as between the results of the mindfulness inventories.

When all 16 participants of the experimental group were analyzed only a moderate negative significant correlation between shooting score and Entr_ML as well as between shooting score index sampEntr_ML (*r=-0.66, p=0.006* and *r=-0.54, p=0.03*) was present. When the participants were analyzed separately, as they were divided in the experiment into the "Mindfulnes" and "Stability" groups, the data show more significant correlations between the basic COP and Rambling-Trembling parameters in quiet standing and shooting performance in "Mindfulness" and "Control" groups (see tab. 1-2). In the "Stability" group only sampEntr_ML was correlated with the shooting score and shooting score index (*r=-0.79, p=0.019* and *r=-0.78, p=0.023*).

Table 1. Correlation coefficients and corresponding p level between the shooting performance parameters and posturographic measures in the “Stability group” before the experiment

Variable	rhytm_stab	meanS	meanS_Horiz	meanS_Vert	score	score_indx
raCOP_ML	-,2163	-,1861	-,3201	-,0269	,5859	,7867
	p=,607	p=,659	p=,440	p=,950	p=,127	p=,021
stdCOP_ML	-,4136	-,1965	-,3053	-,0662	,7093	,8308
	p=,308	p=,641	p=,462	p=,876	p=,049	p=,011
rmsCOP_ML	-,4136	-,1965	-,3053	-,0662	,7093	,8308
	p=,308	p=,641	p=,462	p=,876	p=,049	p=,011
raRAMB_ML	-,1766	-,2691	-,4037	-,1027	,6166	,8019
	p=,676	p=,519	p=,321	p=,809	p=,103	p=,017
stdRAMB_ML	-,4207	-,2068	-,3159	-,0756	,7347	,8289
	p=,299	p=,623	p=,446	p=,859	p=,038	p=,011
rmsRAMB_ML	-,4207	-,2068	-,3159	-,0756	,7347	,8289
	p=,299	p=,623	p=,446	p=,859	p=,038	p=,011
sampEntr_ml	,2922	,1144	,3182	-,1245	-,7084	-,4429
	p=,482	p=,787	p=,442	p=,769	p=,049	p=,272

Table 2. Correlation coefficients and corresponding p level between the shooting performance parameters and posturographic measures in the “Control group” before the experiment (p<0.05)

Variable	rhytm_stab	meanS	meanS_Horiz	meanS_Vert	score	score_indx
raCOP_AP	-,6620	,3501	,3062	,4086	-,5041	-,4557
	p=,037	p=,321	p=,390	p=,241	p=,137	p=,186
stdCOP_AP	-,6734	,5214	,4384	,6112	-,4508	-,4105
	p=,033	p=,122	p=,205	p=,060	p=,191	p=,239
rmsCOP_AP	-,6734	,5214	,4384	,6112	-,4508	-,4105
	p=,033	p=,122	p=,205	p=,060	p=,191	p=,239
lenCOP_AP	-,7252	-,1781	-,2207	-,0810	-,2433	-,1866
	p=,018	p=,623	p=,540	p=,824	p=,498	p=,606
vCOP_AP	-,7252	-,1781	-,2207	-,0810	-,2433	-,1866
	p=,018	p=,623	p=,540	p=,824	p=,498	p=,606
stdRAMB_AP	-,5927	,5947	,5002	,6905	-,4578	-,4078
	p=,071	p=,070	p=,141	p=,027	p=,183	p=,242
rmsRAMB_AP	-,5927	,5947	,5002	,6905	-,4578	-,4078
	p=,071	p=,070	p=,141	p=,027	p=,183	p=,242
stdTREMB_AP	-,7498	-,3958	-,3579	-,3806	-,1882	-,1763
	p=,013	p=,258	p=,310	p=,278	p=,603	p=,626
rmsTREMB_AP	-,7498	-,3958	-,3579	-,3806	-,1882	-,1763

	p=,013	p=,258	p=,310	p=,278	p=,603	p=,626
lenTREMBD_AP	-,7327	-,2341	-,2734	-,1443	-,1338	-,1094
	p=,016	p=,515	p=,445	p=,691	p=,713	p=,764
vTREMB_AP	-,7327	-,2341	-,2734	-,1443	-,1338	-,1094
	p=,016	p=,515	p=,445	p=,691	p=,713	p=,764
raTREMB_ML	-,7259	-,0088	-,0461	,0592	-,4959	-,3977
	p=,017	p=,981	p=,899	p=,871	p=,145	p=,255
std_TREMB_ML	-,6791	,1378	,0666	,2321	-,4368	-,3832
	p=,031	p=,704	p=,855	p=,519	p=,207	p=,274
rmsTREMB_ML	-,6791	,1378	,0666	,2321	-,4368	-,3832
	p=,031	p=,704	p=,855	p=,519	p=,207	p=,274

Second, the associations between the Mindfulness inventories and shooting performance was evaluated. Only the Control group showed significant positive correlations between refocusing variable and shooting score as well as shooting score index (r=0.7, p=0.024 and r=0.68, p=0.03) before the experimental phase of the project. However, these interdependencies have emerged after the employed trainings. There was significant positive correlation in the stability group between shooting score and awareness as well as self confidence (r=0.84, p=0.008 and r=0.87, p=0.006). There were more significant correlations in the “Mindfulness” group (tab. 3). No significant correlations were found in the control group after the training.

Table 3. Significant correlations in the Mindfulness group between shooting performance and Mindfulness inventories after the training (p<0.05)

Variable	Awareness	Distractions	CH_mean_rt	CH_long_rt
shooting score	,7150	-,7247	-,8240	-,7247
	p=,046	p=,042	p=,012	p=,042

Next, we wanted to verify whether there are significant correlations between the Laser tracker data and balance performance. We have hypothesized that there should be strong dependence between these signals and this was confirmed. Substantial number of variables were significantly correlated with each other and were presented in the table 4. Due to the limited space of this report and large database not all significant correlations were presented. However, more thorough analysis of the results shall be presented in the future publications.

Table 4. Pearson correlation coefficients and respective p level between Laser tracker data and posturographic parameters

Variable	s_Y		V_Y		s_Total		V_total	
	r	p	r	p	r	p	r	p
lenCOP_AP	0.74	0.035	0.74	0.035	0.5652	0.144	0.5652	0.144
vCOP_AP	0.74	0.035	0.74	0.035	0.5644	0.145	0.5644	0.145
stdTREMB_AP	0.74	0.037	0.74	0.037	0.6476	0.083	0.6476	0.083
lenTREMB_AP	0.77	0.027	0.77	0.027	0.6423	0.086	0.6423	0.086
vTREMB_AP	0.77	0.027	0.77	0.027	0.6418	0.086	0.6418	0.086
stdCOP_ML	0.82	0.013	0.82	0.013	0.7805	0.022	0.7805	0.022
raRAMB_ML	0.7	0.054	0.6987	0.054	0.7165	0.046	0.7165	0.046
stdRAMB_ML	0.82	0.013	0.82	0.013	0.7609	0.028	0.7609	0.028

Finally, the results of the effectiveness of the implemented training approaches to the shooting performance were analyzed. The results showed that there was a tendency to improve shooting accuracy however these improvements were not statistically significant in all groups. The cause of the lack of significant differences in pre and post measurement were shortly discussed in the limitation of the study.

Since one of the implemented trainings was directed to improve balance performance, therefore we have conducted an analysis aimed to show the effect of this training. The results showed several statistically significant differences pre and post trainings in the stability while aiming in the Stability group as well as in the Mindfulness group. No such changes were observed in the control group.

There were no significant changes in the functional balance estimated with the use of the YBT except for the Control group. However, it should be noted that the control group presented significantly lower scores in comparison to the experimental group and had higher potential for improvement. There was a tendency in the results that indicated better results of the Stability group, however these differences were not statistically significant.

Ultimately, the analysis of the tracked laser data was conducted. It is reflecting characteristics of aiming to the shooting target, in other words the stability of the rifle while aiming. This analysis was especially interesting in the fatigue condition. It is obvious that the trajectories of aiming will be significantly different before and after fatigue (see pic. 2). However, after the training we have discovered different tendencies of changes in this signal between the groups. The “Stability” group presented lower scores in most parameters suggesting more focused aiming trajectory. On the other hand, the “Mindfulness” group presented slightly higher values of these parameters in

most cases. Unfortunately, these differences were not statistically significant and one can only suggest some tendencies. Finally, the control group showed statistically significant different results in most cases towards the higher values, meaning that their aiming trajectory was less focused and more variable.

3.4. Research findings and prospects

The most important finding of the research and its potential value is the confirmation of the hypothesis that the body balance and the level of mindfulness can significantly contribute to the shooting accuracy. Thanks to the project we have managed to establish prospective cooperation with the Polish Biathlon Union and we believe that the results of this study can be used in the senior level of competitions.

The proposed balance training accentuated lower quarter of the body. The training was created based on the information gained from the trainers and apart from the effects that were visible in the change of the posturographic parameters, it also could elicit positive changes in the more dynamic performance like skiing. Unfortunately, this was not evaluated and only individual reports from the study participants' confirm this hypothesis. We are now trying to find some objective methods to confirm this hypothesis in the future.

In the project the data was analyzed globally and averaged. However, it is worth to report that some individuals are more susceptible to interventions than the others. Again, the individual statements of the participants were quite positive, especially with respect to the MSPE training. They reported that they were able to cope with the stress and to refocus much better with the use of the methods they were presented within the course of the project. Although, the participants had some experience with psychological training, the MSPE was a novelty for all the participants. Currently we plan to incorporate both trainings in the control group with the use of the created database and media withing the online platform created thanks to the project.

Finally, the developed methodology concerning the tracking of the aiming trajectory brought an interesting result, however not statistically significant. Presumably, the proposed balance training has led to better control of the rifle during aiming and resulted in a more focused tracing. This should be further explored in the future experiments. The lack of significant changes could be explained partly with the issues mentioned in the limitations of the study. Also, based on this interesting outcome we would propose a motor training which would be more focused on the upper quarter of the body, to functionally enhance the aiming performance.

3.5. Study limitations

First, one study limitation is the small number of participants. The inference coming from this study can't be generalized to wide population. However, the results are promising and confirm our hypothesis that the balance and mindfulness are the factors that might influence the shooting performance. Second, which is on one hand limitation and on the other hand strong point, is that we were working with young competitors. They are sometimes not that focused on the best results of the training like the senior competitors, and the sports training is not the most important to them. We still managed to achieve positive results with this group and we hope for even better results with higher level of competitors. Moreover, due to the time scope of the project we were obliged to incorporate the training during the ongoing competitive season. It might be possible to have better results when the program would be completed before the competition season stars. Finally, not the last study limitation is the use of the Scatt shooting system for the performance analysis. Scatt, being a training system, is a decent tool for dry shooting training. However, it does not reflect the actual shooting that is executed during the competition. We believe that we could have better results when we could analyze actual shooting results from the shooting range.

4. References:

1. *Birrer D, Morgan G. Psychological skills trainings as a way to enhance an athlete's performance in high-intensity sports. Scand J Med Sci Sports. 2010;20:78–87.*
2. *Ball KA, Best RJ, Wrigley TV. (2003). Body sway, aim point fluctuation and performance in rifle shooters: inter- and intra- individual analysis. J Sports Sci ; 21 (7): 559-66*
3. *Mononen K, Konttinen N, Viitasalo J. (2007). Relationship be- tween postural balance, rifle stability and shooting accuracy among novice rifle shooters. Scand J Med Sci Sports ; 17 (2): 180-5*
4. *Mason BR, Pelgrim PP. (1986). Body stability and performance in archery. Excel ; 3 (2): 17-20*
5. *Ashton-Miller JA, Wojtys EM, Huston LJ, et al. (2001). Can proprioception really be improved by exercises? Knee Surg Sports Traumatol Arthrosc ; 9 (3): 128-36*
6. *Taube W, Gruber M, Gollhofer A. (2008). Spinal and supraspinal adaptations associated with balance training and their functional relevance. Acta Physiol; 193 (2): 101-16*
7. *Lloyd D. (2001). Rationale for training programs to reduce anterior cruciate ligament injuries in Australian football. J Orthop Sports Phys Ther ; 31 (11): 645-54Jackson, S. A., & Eklund, R. C. (2002). Assessing Flow in Physical Activity: The Flow State Scale-2 and Dispositional Flow Scale-2. Journal of Sport & Exercise Psychology, 24(2), 133–150.*

8. *Hasker SM. Evaluation of the mindfulness-acceptance-commitment (MAC) approach for enhancing athletic performance. Indiana University of Pennsylvania; 2010.*
9. *Kabat-Zinn J. Wherever you go there you are. New York: Delta; 1994.*
10. *Brown KW, Ryan RM. The benefits of being present: mindfulness and its role in psychological well-being. J Personal Soc Psychol. 2003;84:822–48.*
11. *Bergomi C, Tschacher W, Kupper Z. Meditation practice and self-reported mindfulness: a cross-sectional investigation of meditators and non-meditators using the comprehensive inventory of mindfulness experiences (CHIME). Mindfulness. 2015;6(6):1411–21.*
12. *Cebolla A, Campos D, Galiana L, et al. Exploring relations among mindfulness facets and various meditation practices: Do they work in different ways? Conscious Cognit. 2017;49: 172–80.*
13. *Moore ZE. Theoretical and empirical developments of the mindfulness-acceptance-commitment (MAC) approach to performance enhancement. J Clin Sport Psychol. 2009;25(4):291.*
14. *Pineau TR, Glass CR, Kaufman KA. Mindfulness in sport performance. In: Ie A, Ngnoumen CT, Langer EJ, editors. Handbook of mindfulness. Oxford: Wiley-Blackwell; 2014: p. 1004–34.*
15. *Kabat-Zinn J, Beall B, Rippe J. A systematic mental training program based on mindfulness meditation to optimize performance in collegiate and Olympic rowers. Poster presented at the World Congress in Sport Psychology, Copenhagen, Denmark; 1985*
16. *Gardner FL, Moore ZE. A mindfulness-acceptance-commitment- based approach to athletic performance enhancement: theoretical considerations. Behav Ther. 2004;35(4):707–23.*
17. *Kaufman KA, Glass CR, Arnkoff DB. Evaluation of mindful sport performance enhancement (MSPE): A new approach to promote flow in athletes. J Clin Sport Psychol. 2009;25(4):334.*
18. *Baltzell AL. Mindfulness and performance. Cambridge: University Press; 2016.*
19. *Bühlmayer, L., Birrer, D., Röthlin, P., Faude, O., and Donath, L. (2017). Effects of mindfulness practice on performance-relevant parameters and performance outcomes in sports: a meta-analytical review. Sports Med. 47, 2309–2321. doi: 10.1007/s40279-017-0752-9*
20. *Noetel, M., Ciarrochi, J., Van Zanden, B., and Lonsdale, C. (2019). Mindfulness and acceptance approaches to sporting performance enhancement: a systematic review. Int. Rev. Sport Exerc. Psychol. 12, 139–175. doi: 10.1080/1750984X.2017.1387803*
21. *John, S., Verma, S. K., and Khanna, G. L. (2011). The effect of mindfulness meditation on HPA-Axis in pre-competition stress in sports performance of elite shooters. Natl. J. Integr. Res. Med. 2, 15–21.*
22. *Zhang, C. Q., Si, G., Duan, Y., Lyu, Y., Keatley, D. A., and Chan, D. K. C. (2016). The effects of mindfulness training on beginners' skill acquisition in dart throwing:*

a randomized controlled trial. Psychol. Sport Exerc. 22, 279–285. doi: 10.1016/j.psychsport.2015.09.005

23. *Birrer, D., Röthlin, P., and Morgan, G. (2012). Mindfulness to enhance athletic performance: theoretical considerations and possible impact mechanisms. Mindfulness 3, 235–246. doi: 10.1007/s12671-012-0109-2*
24. *Kaufman, K. A., Glass, C. R., and Arnkoff, D. B. (2009). Evaluation of mindful sport performance enhancement (MSPE): a new approach to promote flow in athletes. J. Clin. Sport Psychol. 3, 334–356. doi: 10.1123/jcsp.3.4.334*
25. *Thompson, R. W., Kaufman, K. A., De Petrillo, L. A., Glass, C. R., and Arnkoff, D. B. (2011). One year follow-up of mindful sport performance enhancement (MSPE) with archers, golfers, and runners. J. Clin. Sport Psychol. 5, 99–116. doi: 10.1123/jcsp.5.2.99*
26. *Wu, T.-Y., Nien, J.-T., Kuan, G., Wu, C.-H., Chang, Y.-C., Chen, H.-C., & Chang, Y.-K. (2021). The Effects of Mindfulness-Based Intervention on Shooting Performance and Cognitive Functions in Archers. Frontiers in Psychology, 12(June), 1–10. https://doi.org/10.3389/fpsyg.2021.661961*
27. *Josefsson, T., Gustafsson, H., Iversen Rostad, T., Gardner, F. L., & Ivarsson, A. (2021). Mindfulness and shooting performance in biathlon. A prospective study. European Journal of Sport Science, 21(8), 1176–1182. https://doi.org/10.1080/17461391.2020.1821787*
28. *Kaufman K. A., Glass C. R., and Pineau T. R. (2002). Mindful Sport Performance Enhancement: Mental Training for Athletes and Coaches. American Psychological Association. Washington, DC*
29. *Thienot, E., Jackson, B., Dimmock, J., Grove, J. R., Bernier, M., & Fournier, J. F. (2014). Development and preliminary validation of the mindfulness inventory for sport. Psychology of Sport and Exercise, 15(1), 72–80. https://doi.org/10.1016/j.psychsport.2013.10.003*
30. *Smith, R.E., Smoll, F.L., Cumming, S.P., & Grossbard, J.R. (2006). Measurement of multidimensional sport performance anxiety in children and adults: The Sport Anxiety Scale-2. Journal of Sport and Exercise Psychology, 28, 479-501.*
31. *Sheard, M., Golby, J., & van Wersch, A. (2009). Progress toward construct validation of the Sports Mental Toughness Questionnaire (SMTQ). European Journal of Psychological Assessment, 25, 186-193.*
32. Vealey, R. S. (1986). Conceptualization of sport-confidence and competitive orientation: Preliminary investigation and instrument development. *Journal of Sport Psychology*, *8*, 221-246.
33. *Zatsiorsky V. M. and Duarte M., (2000). Rambling and Trembling in Quiet Standing. Motor Control, vol. 4, no. 2, pp. 185–200, Apr., doi: 10.1123/mcj.4.2.185.*

5. Annexes

5.1. Balance enhancement training program dedicated to Biathlon (compact version)

Training Unit (Phase I)

Warm-up

Excercise	Time [s]
Runnin forward	30
Running backwards	30
Run with arms circling, one at the time, alternating	30
Shuttle run	30 per side
Torso rotations plus stretching of the inner thigh in the low step position of 60 s	60
Running in place plus stretching the quadriceps or buttock 60 s	60
Skip A 50% intensity 30 s	30
Skip C 50% intensity 30 s	30

Remark! In the first week of Phase II of the program, perform 2 series. In the second, increase the number of series to 3.

Core stability

Excercise	Time [s]	Rest between side change [s]	Rest between series [s]	Series	Reps.
Activation of the buttock with the foot on the wall	-	0	30	2 x side	30
Dead bug	-	0	30	2 x side	15
Lifting one leg standing	60	0	30	2 x side	-

Plyometrics

Excercise	Powt.	Serie	Rest between series [s]
Landing exercise/Learning	10	2	30

Functional training

Excercise	Reps.	Series	Rest between side change [s]	Rest between series [s]
Torso rotations in position 90/90	15	2	-	60
Squat with push-up	15	2	-	60
Rotations in the deadlift position on one leg	15	2 x strona	0	60
Lifting hips on one leg	15	2 x strona	0	60

Stretching*

Muscle group	Series	Time [s]	Muscle group	Series	Time [s]
Latissimus dorsi	1	2x60	Triceps calf	1	2x60
Hamstrings	1	2x60	Quadriceps thighs	1	2x60
Hip flexors	1	2x60	Pectoralis	1	2x60
Adductors of the thigh	1	60	Gluteus	1	2x60

Training Unit (Phase II)

Warm-up -The same as in Phase I

Remark! In the first week of Phase II of the program, perform 2 series. In the second, increase the number of series to 3.

Core stability

Excercise	Reps.	Time [s]	Rest between side change [s]	Rest between series [s]	Serie
Plank with rotation	-	60	0	60	2
Hollow body	15	-	0	60	2
Monster	-	60	0	60	2

Playometrics

Excercise	Reps.	Series	Rest between series [s]
Landing on one leg	5 x L, R	2	60
Side jumps over rope	5	2	120
Jumps from the box	5	2	60

Functional training

Excercise	Reps.	Time[s]	Series	Rest between side change [s]	Rest between series [s]
Antirotation in the athletic	15		2 x strona	0	60
Deadlift on one leg	15		2 x strona	0	60
Gait with overhead load	-	30	2	0	60

Stretching – the same as in the Phase I*

Training Unit (Phase III)

Warm-up -The same as in Phase I

Remark! In the first week of Phase III of the program, perform 2 series. In the second, increase the number of series to 3.

Core stability

Excercise	Reps.	Time [s]	Rest between side change [s]	Rest between series [s]	Series
Reverse plank	15/leg	-	0	60	2
Bear walk	-	2x30 (przód, tył)	0	60	2
Monster walk	15 L i R	-	0	60	2

Playometrics

Excercise	Reps.	Series	Rest between series [s]
Side jumps on one leg over rope	5 x L,R	2	120
Jumps over hurdle	5 x L,R	2	120

Functional training

Excercise	Reps.	Time [s]	Series	Rest between side change [s]	Rest between series [s]
Partial Turkish get-up	2*	-	2 x side	0	60
Deadlift on one leg on mattress	15	-	2 x side	0	60
Lunge squat on mattress	15	-	2 x side	0	60
Push-up with dynamic push	10 + 5	-	2	0	60

*** in second week do 3 repetitions**

Stretching – the same as in the Phase I*