

# A technical method for effecting stability in sports: A case study of biathlon and air-pistol shooting sports

Tongling Wang\*, Cuiqing Zhao\*\*, Dawei Yu\*\*\*

(\*) Institute of Physical Education, Huzhou University, Huzhou, Zhejiang, China

(\*\*) Sport and Leisure Industry Studies, Myongji University, Seoul, South Korea

(\*\*\*) Institute of Physical Education, Huzhou University, Huzhou, Zhejiang, China

*Shooting sports require a high level of stability to achieve accuracy and precision in hitting the target. This study presents a technical method for effecting stability in shooting sports by analyzing a case study of the sport. This study examines how stability could improve in shooting sports through technical methods. The research found that selecting the right equipment, maintaining correct body posture, and practicing breathing techniques could enhance stability. Mental preparation and relaxation techniques are also beneficial. Physiological factors like muscle tension and breathing rate influence stability. The study provides guidance for coaches, trainers, and athletes to improve performance in shooting sports.*

KEY WORDS: Sports; Shooting; stability.

## 1. Introduction

The importance of stability in sports performance cannot be overstated. Athletes must maintain control over their body and equipment during high-intensity activities to achieve optimal results. This study focuses on two specific sports, biathlon and air-pistol shooting, and presents a technical method for improving stability in these sports. Biathlon involves a combination of cross-country skiing and rifle shooting, while air-pistol shooting requires precise aim and control over a firearm (Sattlecker et al., 2014). Both sports require significant physical exertion and the ability to maintain stability during competition. The study examines the biomechanics of stability in these sports and presents a method for enhancing stability through specialized training techniques. The case study was conducted in China, where these

---

Correspondence to: Cuiqing Zhao, Sport and Leisure Industry Studies, Myongji University, 17060 Seoul, South Korea. (E-mail: cuiqingzhao521@163.com).

sports are highly competitive and have a large following. The study aims to contribute to the ongoing research on sports biomechanics and provide practical guidance for coaches and athletes looking to improve their performance in these disciplines. The study explores how stability is important in sports like biathlon and air-pistol shooting. These sports require athletes to be stable in order to hit their targets accurately. The study presents a method for improving stability in these sports by analyzing a case study. It found that choosing the right equipment, maintaining proper body posture, and practicing breathing techniques could help enhance stability. Mental preparation and relaxation techniques are also beneficial.

**Biathlon:** Biathlon is a demanding sport that combines cross-country skiing over distances ranging from 6 to 20 km with rifle shooting in 5-shot clips, all performed under high physical load (Hoffman & Street, 1992). The athletes' ski skating performance, with average heart rates of 93% of their maximum, and shooting accuracy and speed determine competition results, particularly in long distance races with 20 shots. Biathlon shooting has significantly improved over the last decade, with higher scores and faster shooting times down to 16 seconds due to improved training methods (Hoffman et al., 1992). Basic training is performed without physical load to enhance fun-



Fig. 1. - Biathlon sample image.

damental motor skills of shooting technique, while shooting under physical stress serves to stabilize the technique under fatigue.

Koyakka (Köykkä et al., 2021) investigated differences in shooting performance and performance-related factors between two different aiming strategies (HOLD, low radial velocity during the approach 0.4-0.2 seconds before triggering, and TIMING, high radial velocity) in biathlon standing shooting. Koyakka (Köykkä et al., 2022) investigated the most important factors determining biathlon prone shooting performance. Koyakka identified four technical components in biathlon prone shooting: stability of hold, aiming accuracy, cleanness of triggering, and timing of triggering.

Despite the sport's popularity, there is a lack of current studies on biathlon shooting technique and its biomechanical performance factors in athletes belonging to different performance squads (Gros Lambert et al., 1999). The present study aimed to investigate differences in postural balance and rifle stability between athletes of three different categories of squads and relationships between shooting scores and various balance and stability factors, specifically examining fundamental skills in the standing shooting technique under standardized conditions on an indoor gun range (Era et al., 1996). The study hypothesized that elite athletes would show a more stable rifle position and less body sway than lower level groups and that body and rifle sway would be negatively related to shooting performance (Mononen et al., 2007). In biathlon, standing shooting stability of stance and rifle hold believed to be essential aspects affecting performance, but this area has little investigated in the discipline. Previous studies have indicated that low rifle and body sway were main performance determining factors in similar sports like rifle and pistol shooting, differentiating high from lower level athletes (Konttinen et al., 1999; Sattlecker et al., 2014).

**Air –Pistol Shooting:** Air pistol shooting is a competitive Olympic sport that involves hitting the center of a target 60 times in a row. The target has rings ranging from 1.0 to 10.9, with a diameter of 11 mm for the 10-ring. Men and women compete in separate events, but since 2017, both genders fire 60 competition shots, and the top eight shooters qualify for the final. During the 2019 world cup season, the average score for qualification was  $581.4 \pm 1.3$  for men and  $576.8 \pm 1.8$  for women (Olsson and Laaksonen, 2021).

Shooting, including air pistol shooting, is a challenging activity that requires excellent fine motor control and postural stability. Optoelectronic training systems are often used to improve shooting technique by recording and measuring barrel movements during aiming time (Hawkins, 2013; Mon-López et al., 2022). Several studies have investigated the components of shooting technique that should be prioritized by athletes, with a particular focus on stability of hold and postural stability.

Numerous studies have shown that postural stability affects shooting performance, and elite shooters in air rifle and air pistol shooting have found to have better stability than novice shooters. Additionally, stability of hold is a more accurate measure than stability of posture (Ihalainen et al., 2016). In air rifle shooting, the stability of hold alone explains up to 54% of the variance in shooting score, while in air pistol shooting, it explains up to 33%. Similar results have reported for running target.

## **2. Case Study: Method of Analysis Over Biathlon Shooting Sports**

The score for shooting was determined using a scale ranging from 0, to 10, with 0 indicating a missed shot and 10 indicating the center of the target. To ensure that all shots were included in the analysis, the time of shooting was identify based on the visual inspection of each shot's sound and all variables were calculate within a time interval of 0.6 seconds prior to the trigger pull. Since all subjects in the study were at least 15 years old, no maturation-related correction of the balance data was performed, as previous studies have



Fig. 2. - Air pistol shooting training.

shown that 15-year-old adolescents have similar balance responses to adults and reach optimal stance at this age (Konttinen et al., 1999).

Prior to the calculation of any variables, random noise in kinematic signals was eliminated using a quantic spline filter following Woltring (Woltring, 1995). Joint centers and segment orientation were calculate for various body segments, including the thorax, pelvis, arms, legs, and feet, based on anthropometric data and the positions of reflecting markers. The center of mass (COM) of the entire body was also defined using established parameters (Era et al., 1996).

Kinematic variables were measured using mean sway velocity (VEL) and range of motion (ROM) of the COM and rifle in various directions. Kinetic variables were quantified using the standard deviation (DEV) and ROM of the COP in the front and back legs in the x- and y-directions, the DEV and ROM of the load distribution (LD) between the front and back legs, and the DEV and ROM of the rifle force (RF) in the back shoulder (Mononen et al., 2007).

C) The biathletes who participated in this study exhibited lower mean sway velocities during the 5-shot clips compared to their counterparts in the other skill groups. This was particularly evident in the cross-shooting direction, with WC and EC biathletes demonstrating 31% and 18% smaller mean sway velocities, respectively. These results corroborate the findings of previous studies conducted by (Mononen et al., 2003), which showed that rifle stability is an important factor distinguishing between different skill groups. The present study also revealed a connection between the control of body and rifle movements, with less rifle instability related to better postural balance among the biathletes. This connection may partly explained by two specific actions that biathletes take during the standing shooting position: the solid shoring of the front arm elbow in the hip and the pulling of the gun into the back shoulder. These actions provide a more rigid whole body system and support an optimal body-rifle connection (Grüneberg et al., 2004). However, excessive stiffening of the body-rifle system could be disadvantageous, as it may increase instability or the probability of losing balance. Interestingly, elite athletes in pistol and running target shooting have been shown to manage body sway and gun movement independently, due to the fact that the supporting arm resting in the hip or the chest is missing, resulting in a more flexible system where postural sway and rifle stability may be controlled separately.

## 2.2 POSTURAL BALANCE CONTROL FOR BIATHLON

Compared to the WC and EC groups, the youth athletes exhibited significantly larger COP deviations in both front and back leg in the cross-shooting

(x) direction by 45 to 64% and 33-70% in the shooting direction (y). Furthermore, the youth athletes showed a 1.5-fold deviation of load distribution, up to 18% larger total mean sway velocities, and 21-27% greater mean sway velocities in cross-shooting direction. These findings are consistent with earlier studies on rifle shooting, which showed better control of posture in trained athletes with smaller body sway amplitudes (Mononen et al., 2003) (Fig. 3).

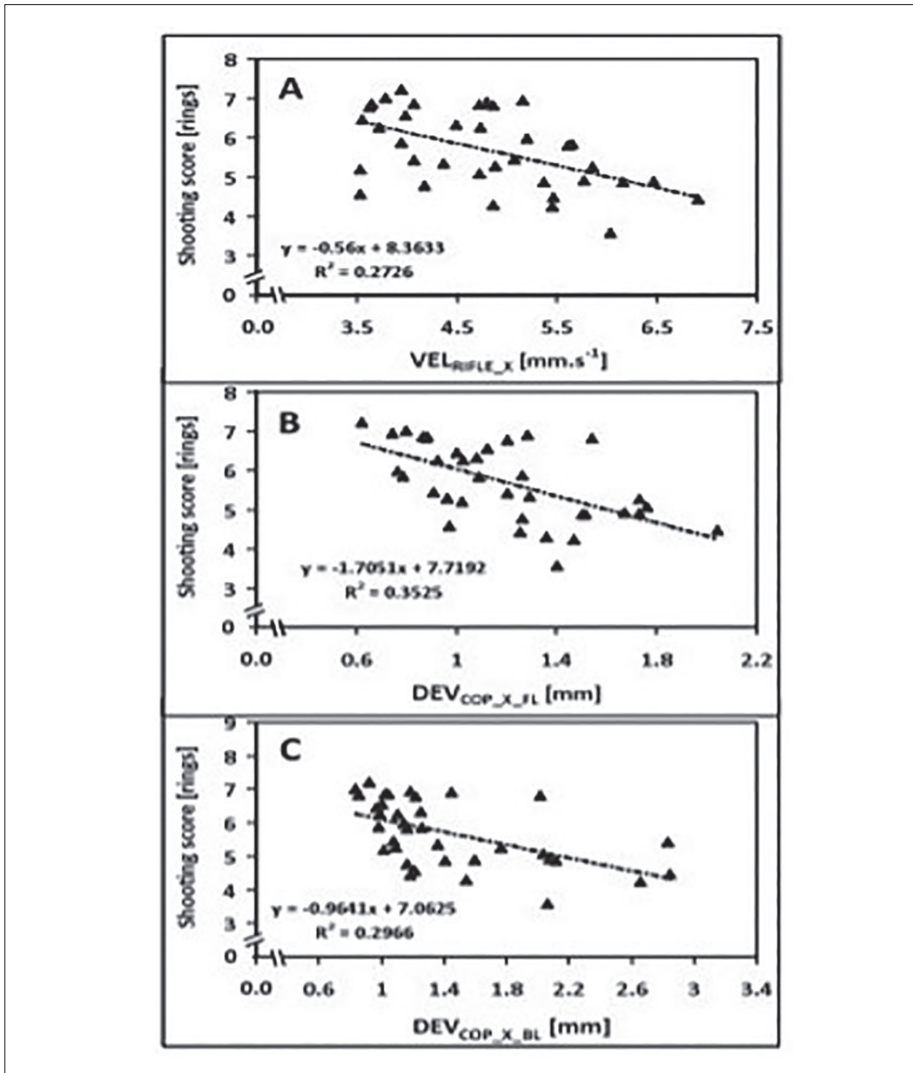


Fig. 3. - Biathlon Shooting Sport in standing position (Sattlecker et al., 2014).

The study found that the lower body oscillation in cross-shooting (x) direction was the most sensitive factor for distinguishing various age and/or skill groups in rifle shooting. Task-specific neural adaptations, balance strategies, and load/unload mechanisms were found to influence body sway. The results showed that the older and more experienced biathletes with more training and competition experience had better task-specific standing shooting position control than the youth athletes. The youth athletes had higher COP deviations, especially in cross-shooting (x) direction, indicating specific shortcomings in postural balance. The study suggests that in common standing shooting; the Medio-lateral ankle joint mobility is reduced due to the feet being positioned apart from each other. This means that small body sway in shooting direction may not significantly affect the targeting process during shooting.

However, body sway across the shooting or/and anterior-posterior direction has a more negative effect on the shooting score. The study recommends further investigations into individual adaptation and variation in foot positions during standing shooting to improve balance (Grüneberg et al., 2004).

### 3. Method of Analysis – Pistol Sports

The study involved 18 national-level air pistol shooters, comprising of 8 males and 10 females, with an average age of  $38 \pm 17$  years. On average, they had been participating in air pistol shooting for  $13 \pm 13$  years and had a personal best of  $564.3 \pm 13.1$  points. To be included in the study, participants had to be ranked in the top 30 of the Swedish ranking list for Men's, Women's, Junior Men's, or Junior Women's air pistol from September 1, 2019, to March 31, 2020, based on their four best results within the previous year. Prior to testing, participants were providing with written and oral information about the project's aims, data collection, and management, and they signed an informed consent. All data collected and kept confidential, anonymous, and ethical approval was not required as no personal information, aside from age and shooting data, was gathered. (Olsson and Laaksonen, 2021)

#### 3.1 POSTURAL BALANCE FOR AIR PISTOL

The Noptel ST 2000 NOS4 optoelectronic training system (Noptel Inc., Oulu, Finland) was used to measure shooting scores (with decimals) and aiming point trajectory. The training device comprised of an optical transmitter-receiver unit (weighing 80 g) and a reflector tape, which was affixed around the

target Centre (on the line of the 5-ring). Every competition shot (60 per participant, 1080 test shots) recorded for shooting score and aiming point trajectory at 100 Hz sampling rate. The Noptel training device reported to have an accuracy of 0.1 mm. During the test session, only shooting score and hit placement were shown to the participants, similar to a real-life competition situation. The aiming trajectory data were shown to participants after the test session to avoid influencing their shooting technique. (Olsson & Laaksonen, 2021).

### 3.2 TECHNICAL COMPONENTS OF AIR PISTOL

Previous studies on shooting technical components in running target, air rifle, and air pistol have utilized principal component analysis (PCA). Given that the present study includes more variables than prior studies on air pistol shooting, PCA was once again used to identify key technical components. To achieve this, PCA with varimax rotation was utilized to create orthogonal linear combinations from aiming point variables. The number of components was determined using a minimum eigenvalue of 0.9 and by ensuring that at least 5% of the variance was accounted for by the component. (Ihalainen et al., 2016).

For shot score and aiming point trajectory data, mean values were calculated for each participant. The Two-Tailed Pearson's correlation coefficient analysis was used to assess the relationship between shooting performance and technical variables. To determine the amount of explained variance in shooting performance by technical variables, two stepwise multiple regression analyses were conducted. In the first stepwise multiple regression analysis (MRA1), only variables loading on more than one component in PCA were excluded. In the second stepwise multiple regression analysis (MRA2), only the one variable with the strongest correlation with mean shot score from each component found in PCA was included, if it loaded on only one component in PCA. The purpose of conducting the second stepwise multiple regression analysis was to examine the impact of each component on shooting performance. Collinearity statistics were used to examine the linear association between the predictive variables in the stepwise multiple regression analysis. The alpha level was set at 0.05, and all data was presented as mean  $\pm$  standard deviation.

### 3.3 POSTURAL STABILITY

Postural stability is a crucial component in shooting sports such as Biathlon, rifle shooting, and pistol shooting. It refers to the ability to maintain



a stable and balanced shooting stance throughout the shooting process, from the initial position to the follow-through. Good postural stability is essential for accuracy, as even slight movements or deviations can significantly affect the shot placement. In shooting sports, the shooter must maintain a stable position to minimize the effects of external factors such as wind or recoil (Gianikellis, 2000) (Fig. 4).

To achieve postural stability, the shooter must first have a solid foundation with both feet firmly planted on the ground, shoulder-width apart. The weight should be distributed evenly on both feet, with a slight bend in the knees. The upper body should be relaxed, with the shoulders down and the chest slightly forward. In rifle and pistol shooting, the shooter must also maintain a consistent grip on the firearm and support it with the non-firing hand. The firearm should be held at shoulder level, with the shooter's dominant eye aligned with the sights. Archery requires a slightly different stance, with the shooter's feet perpendicular to the target and the bow arm extended straight out. The bowstring should be pulled back with a consistent amount of force, and the shooter's dominant eye should be aligned with the sight pin.

Postural stability can be improved through regular practice and training, including exercises to strengthen the core muscles and improves balance. A coach or trainer can also provide feedback and guidance on proper posture and technique (Ihalainen et al., 2018).

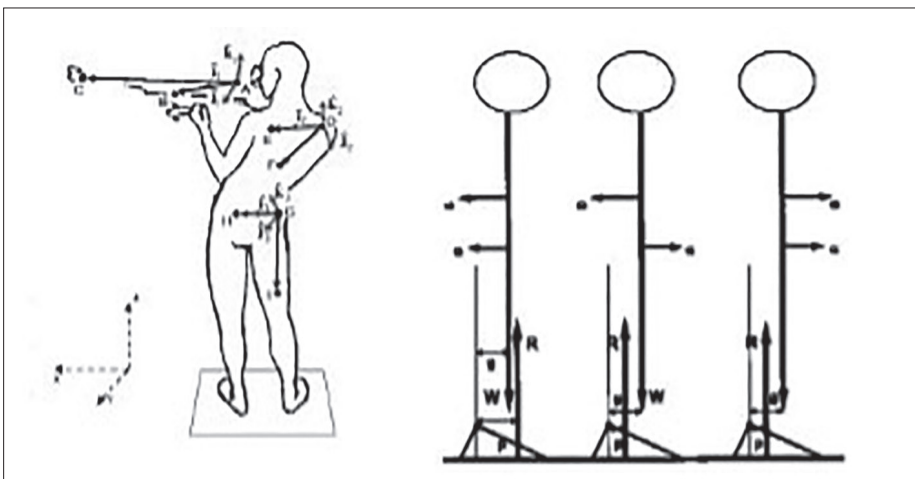


Fig. 4. - Postural stability (Gianikellis, 2000).

Postural stability is crucial in shooting sports, as it allows the shooter to maintain a stable and balanced position for accurate shots. With proper training and practice, shooters can improve their postural stability and increase their accuracy on the range or in competition (Olsson & Laaksonen, 2021).

Shooting requires a precise and coordinated effort of various physiological systems such as the visual, proprioceptive, motor, and neurogenic, respiratory, cardiovascular, endocrine and locomotor systems. Unlike most sports, shooting and archery require the shooter to eliminate any movements that may interfere with the stability of the shooter-gun/bow (S-G/B) system to achieve optimal performance on the target (Hawkins, 2013). According to many coaches, athletes, and training materials, postural stability is a critical factor influencing performance. Postural stability is the result of the interaction between gravity and the mechanical properties of the locomotor system, as well as the control process during aiming. Despite potential physiological and biomechanical factors that could negatively affect performance, elite athletes exhibit impressive precision and control. However, experimental data has shown that the posture adopted by athletes is mechanically unstable due to interactions among the body segments. Therefore, “fine-tuning” the movements at different joints is necessary to balance the posture by eliminating degrees of freedom at the joints. The human body is sometimes modeled as an inverted pendulum in studies on the control of vertical posture, but the problem is much more complex due to the number of joints and the direction of body segment oscillations. Nonetheless, the concept of “synergy” is very close to the “fine-tuning” that ensures the projection of the center of gravity falls within the area of support. Bernstein established some theoretical bases defining synergy as built-in co-ordinated sequences of motor commands to a number of joints leading to a desired common goal. The presence of synergies could simplify the control of vertical posture and the aiming process, solving, at least partially, the problem of mechanical redundancy. Postural synergies are frequently described as combinations of muscle activation patterns for a given perturbation and modulated by local sensory information. (Gianikellis, 2000).

#### **4. Discussion**

Stability is a crucial factor in achieving accuracy and precision in shooting sports, such as biathlon and air-pistol shooting. The study presented a technical method for effecting stability in these sports through a case study.

The research found that selecting the right equipment, maintaining correct body posture, and practicing breathing techniques could enhance stability. Mental preparation and relaxation techniques are also beneficial and physiological factors as muscle tension and breathing rate influence stability.

The study focused on the biomechanics of stability in biathlon and air-pistol shooting sports. In biathlon, the study examined the differences in postural balance and rifle stability between athletes of three different categories of squads and relationships between shooting scores and various balance and stability factors. The study hypothesized that elite athletes would show a more stable rifle position and less body sway than lower level groups, and body and rifle sway would be negatively related to shooting performance. In air-pistol shooting, the study found that postural stability affects shooting performance, and elite shooters have better stability than novice shooters. Additionally, stability of hold is a more accurate measure than stability of posture.

Postural stability is essential in shooting sports, and the shooter must maintain a stable and balanced shooting stance throughout the shooting process, from the initial position to the follow-through. Good postural stability is critical for accuracy, as even slight movements or deviations can significantly affect the shot placement. To achieve postural stability, the shooter must first have a solid foundation with both feet firmly planted on the ground, shoulder-width apart. The weight should be distributed evenly on both feet, with a slight bend in the knees. The upper body should be relaxed, with the shoulders down and the chest slightly forward.

The study provides practical guidance for coaches, trainers, and athletes looking to improve their performance in biathlon and air-pistol shoot-

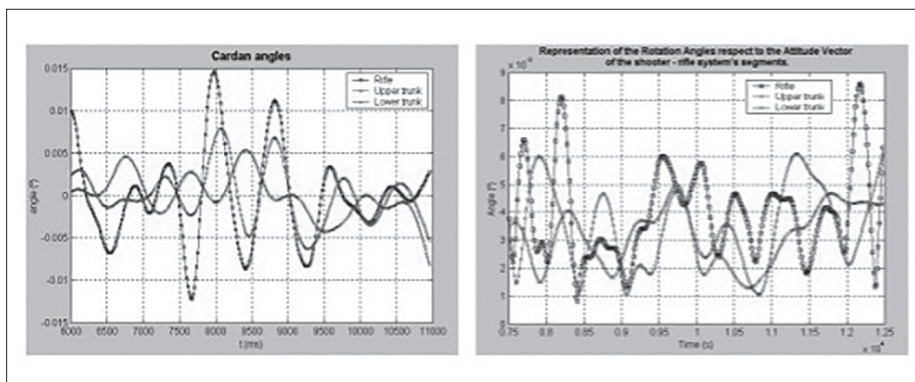


Fig. 5. - Shooter Rifle segmentation system (Gianikellis, 2000).

ing sports. The technical method presented in the study can help athletes enhance stability through specialized training techniques, mental preparation, and relaxation techniques. It is crucial for athletes to focus on postural stability to achieve optimal results in shooting sports. Overall, the study contributes to ongoing research on sports biomechanics and highlights the importance of stability in sports performance.

## **5. Conclusion**

The technical method for effecting stability in sports, as demonstrated through the case studies of biathlon and air-pistol shooting sports, can significantly improve the performance of athletes. Specific workout for developing physical and mental stability, as well as technical improvements to equipment. Will improve athlete's ability to remain stable and concentrated throughout the competition. It is important for coaches and athletes to understand the role of stability in sports and to incorporate training methods that target this key aspect of performance. Overall, this approach has the potential positively influence the success of athletes in a range of sports.

**Declaration of Conflicting Interests:** The Author(s) declare(s) that there is no conflict of interest.