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RESEARCH ARTICLE

The Importance of Bilateral Limb Symmetries in Olympic Clay Shooting: A Prospective Intervention Study

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ABSTRACT

The presented prospective controlled trial investigated the impact of neuromuscular asymmetry correction programs on Olympic clay shooting performance. The examination involved 33 subjects over six weeks, divided into an intervention ($n = 18$) and a control group ($n = 15$). After the initial assessment, subjects in the intervention group were given personalized training protocols to correct the identified asymmetries. The analyses revealed improvements of the intervention group in grip strength asymmetry ($p = 0.012$), single leg balance test ($p = 0.027$), YBT-LQ anterior reach ($p = 0.036$), and composition score ($p < 0.001$) alongside enhanced shooting scores ($p < 0.001$). There were no significant changes in the control group. The findings suggest a direct link between asymmetry correction and shooting accuracy, which agrees with similar research findings of other sports. This is a novel insight into the specific fitness demands for Trap and Skeet athletes and underscores the value of addressing asymmetries and incorporating regular assessments of these parameters in training routines, along with individually tailored corrective programs.

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1. Introduction

A recent study by Peljha *et al*. (2021) focused on determining which fitness parameters strongly correlate to clay shooting performance. Still, none of the tested fitness components (e.g., VO2 max, strength, flexibility) have shown to be significant predictors of performance. The authors noted that the only noteworthy correlation to success in Olympic clay shooting was the bilateral symmetry in shoulder mobility and handgrip strength. The authors concluded that better-performing athletes had smaller asymmetries in these two parameters and suggested that correcting those differences should be part of the clay shooters' training regime.

Studies in other sports suggest that asymmetry correction reduces injuries and improves performance (Daneshjoo *et al*., 2013; Maloney, 2019). According to Guiard (1987), clay target shooting is a bilateral asymmetric motor task. The uneven body action during clay shooting could be best compared to that of a golf player performing the swing with the club, as Cochran and Stobbs (1968) described. Both sports have a common characteristic of a dynamic movement about the vertical axis led by the non-dominant hand.

In addition, Kalata *et al*. (2020) suggest that unilateral limb dominance could be created if asymmetric movement and body position are repeated over long periods and left uncompensated. Further, the authors point out that this shortens the involved muscle tissue and harms joint mobility. In another study, Bishop *et al*. (2017) investigated the effects of lower body asymmetries in track and field and swimming, confirming the negative impact on performance and that a leg asymmetry reduction below 10% could improve performance. However, there is a lack of empirical research on the potential impact of lower body asymmetry on performance in shooting sports (Peljha *et al*., 2021). Thus, the presented study aimed to get further insight into the importance of neuromuscular symmetries on performance in Olympic clay shooting.

The study applied personalized training protocols to minimize detected asymmetries and to investigate their effectiveness in shooting accuracy. This investigation has focused on the two most prestigious clay Olympic shooting disciplines, Skeet and Trap, and purported to explore further the impact of neuromuscular asymmetries on success in these sports.

2. Method

Upon commencement of the study, subjects were evaluated to verify the status of their recent shooting performance and the degree of the asymmetries in their upper and lower body. All subjects participated in a baseline examination, including selected tests for symmetry in bilateral mobility, grip strength, and postural stability. Only shooting scores from the training sessions were considered to avoid the negative impact of psychological pressure during the official competitions. The average shooting score per round of 25 shots from the previous two weeks of training was calculated and registered. After the baseline assessment, subjects of the intervention group were provided with individual exercise programs tailored to minimize the detected neuromuscular asymmetries. In contrast, the control group was informed that the testing was part of their regular fitness assessment and continued with their usual training routine. All subjects were retested after six weeks by repeating the same procedures for comparison. The shooting scores were registered and analyzed over the two weeks following the six-week period, specifically in week 7 and 8. Additionally, the study was continued for another six weeks with 17 of the initial 33 subjects. Due to participation in national and international competitions, 16 subjects could not further continue with the examination.

2.1. *Subjects*

The sample size for this study was determined by conducting a power analysis using the G * Power software (Faul *et al*., 2007). Considering a medium effect size, a significance level of $\alpha = 0.5$, and a desired power of 80%, the resulting sample size was calculated to be 42. Consequently, 44 members of the Cyprus Shooting Federation were initially approached to participate in this study. However, due to the ongoing pandemic, only 33 subjects, eight competing in the female and 25 in the male category ($M_{age} = 29+/-7$ years), could ultimately participate in the study. Performance levels were categorized into club level ($n = 20$) and national level ($n = 13$). The average training score per round of club-level subjects was 19/25, while the average training score for national-level subjects was 22.5/25. All subjects read the information sheet and signed a consent form before taking in the study. The University Ethics Committee (BAHSS518) approved the study based on the ethical principles of the Declaration of Helsinki. The intervention group included 18 subjects (5 females and 13 males, $M_{age} = 29+/-7$ years), while the control group included 15 subjects (3 females and 12 males, $M_{age} = 29+/-6$ age). For the additional 6-week follow-up study, of the remaining 17 subjects, 11 (5 female, 6 males; $M_{age} = 29+/-3$ years) were members of the intervention group, and six males ($M_{age} = 35+/-6$ years) of the control group. All participants were tested on various parameters during a one-hour session. Before each test, information such as gender, age, discipline, and average shooting performance during the previous two weeks of training were recorded. Adequate warm-up was performed before each test to ensure proper preparation and minimize the risk of injury.

2.2. *Analyses*

2.2.1. *Apley's Scratch Test*

Shoulder mobility was assessed using the Apley's Scratch Test. The subjects were asked to stand before and touch a wall with their toes to avoid bending forward during the testing. They were instructed to extend their arms out from the shoulders while making fists with their hands. Subsequently, they were asked to perform a reciprocal reaching pattern with one arm, an external rotation of the shoulder, and an internal rotation with the other arm. The distance between the two closest bony prominences of the fists in this position was measured in centimeters, and the best result out of the three attempts was recorded on each side. The reliability of Apley's Scratch Test is $r = 0.8$ (Dewhurst & Bampouras, 2014).

2.2.2. *Unipedal Stance Test with Eyes Open and Closed*

The test assessed single-leg balance and static postural control. The subjects were asked to stand in their shooting footwear on one leg, with the other foot resting above the ankle of their stance leg, and with their hands on the side of the hips. For the first 30 s, the subjects were instructed to focus on a spot before them and avoid moving their eyes. After the first 30 seconds, they were asked to close their eyes and try to stay static for another 30 s. The examiner used a stopwatch to measure the time the subject could stand on one foot. The timing started when the subject raised the foot off the floor and placed it above the ankle of the tested leg. Time was recorded when the subject either (a) passed the maximum of 60 s, (b) moved/rotated the weight-bearing foot to maintain balance, (c) moved the lifted foot of the weight-bearing leg in order to maintain balance, (d) detached the arms from the hips, (e) opened eyes during the second 30 s of the testing. The procedure was repeated three times on each foot with a 3-minute rest between trials, and the best time was recorded. This test's interrater reliability correlation coefficient is 0.99 (Springer *et al*., 2007).

2.2.3. Handgrip Strength

Handgrip dynamometry was used to assess grip strength and establish the difference between the left and right hand. Subjects were placed in a standing position holding a handgrip dynamometer (Grip D, model TKK 5401, Takei Scientific Instruments, CO., Ltd., Japan). The gripping site was adjusted to each subject so that the second phalange of the hand fit under the handle and was held between the fingers and the palm at the base of the thumb. Subjects were instructed to bend slightly forward, flex the arm to some degree at the elbow, and squeeze as hard as possible for 2–3 s. The procedure was repeated three times on each arm with a 3-minute break between each trial to ensure physical recovery, and the highest measurement for each hand was recorded in kg. Test-retest reliability was reported as $r = 0.94$ (Adams, 1998).

2.2.4. Lower Quarter Y-Balance Test

The lower quarter Y-balance Test (YBT-LQ) is recommended by various authors to identify movement limitations and asymmetries in the lower body (Gorman *et al*., 2012; Shaffer *et al*., 2013). The test kit consists of a stance platform with three pieces attached in the anterior, posteromedial, and posterolateral reach directions. After the examiner gave a visual and verbal demonstration, the subjects had a warm-up trial in order to get familiar with the activity. Bilateral asymmetries were assessed by comparing the results from each leg in all three directions, measured in cm. Additionally, the composition score for each leg was calculated by combining the length of the dominant leg (measured from the anterior superior iliac spine to the medial malleolus) and the results of all three reaching directions. Interrater test-retest reliability of the average reach of 3 trials is $r = 0.85$ to 0.93 (Shaffer & Teyhen, 2007).

2.3. Intervention Program

Individualized intervention programs were formulated, considering the scientific literature's findings on the importance of bilateral symmetry for enhancing performance (Maloney, 2019). The intervention program was added to the subjects' training routines and included adequate warm-up drills followed by corrective exercises. Following the approach of Gonzalo-Skok *et al*. (2017), unilateral training was applied, focusing on the 'weaker' side. The intervention program was tailored for each subject's specific needs from the parameters tested: (a) bilateral difference in shoulder mobility, (b) bilateral difference in handgrip strength, (c) bilateral difference in static single-leg balance, and (d) mobility and dynamic postural control of the lower body. The coaches were informed of the results and ensured the subjects followed the prescribed exercise program. The subjects were instructed to implement the intervention program into their usual training routines. Before the shooting training, mobility and balance exercises were prescribed as part of the warm-up. The grip strength training was recommended for the "non-shooting" days or after the shooting practice to negate any obstructive impact upon performance. A log book for recording the training sessions was handed out to the subjects.

2.3.1. Shoulder Mobility

Subjects were instructed to perform shoulder mobility exercises five times per week (Thomas *et al*., 2018). The program started with dynamic stretching (e.g., across-body arm swings/hugs, large arm circles with an elastic band) for 3–5 minutes. As for the main part, the subjects were instructed to focus on the less mobile side and perform the following exercise instructions:

1. Stand straight, placing the back of the hand on the side flat against the lower back.
2. With the other hand, throw one end of a towel/rope over the shoulder and grab it behind the back with the first hand.
3. Pull gently on the towel with the supporting arm and let the back arm slide up as comfortably as possible.
4. Hold the stretch for 30 s, keeping an upright position.
5. Repeat for three sets with sufficient rests in between (Samson *et al*., 2012)

Additionally, the subjects were advised to perform self-myofascial release for the upper back and shoulders with a foam roller daily.

2.3.2. Single-Leg Static Postural Control

Following the recommendations of Marcori *et al*. (2022), the drills were prescribed 3–5 times per week, either as part of a warm-up before shooting or during fitness training. Based on previous studies (Muehlbauer *et al*., 2012; Rasool & George, 2007), the exercise program provided to the subjects ranged from static single-leg stance (i.e., remaining on one foot for as long as possible) to more complex and dynamic activities to progressively improve their proprioceptive control. The recommended dynamic exercises consisted of five movements: (1) Forward/backward foot drivers, (2) lateral foot drivers, (3) rotational foot drivers, (4) single leg circles, and (5) balance to wall touch. The subjects were instructed to perform each movement slowly and controlled 3–5 times, as Ruiz and Richardson (2005) suggested. The athletes were advised to perform the movements with their eyes closed for further progression. They were given the choice of performing the drills on different surfaces of stability, ranging from solid ground to softer surfaces (e.g., BOSU, balance mats, or pillows).

2.3.3. Single-Leg Dynamic Postural Control and Mobility

Based on the examination of Kang *et al*. (2015), the leading indicators of poor execution and predictors of performance on the YBT-LQ are ankle and hip joint mobility limitations. The emphasis was on performing static and dynamic hip mobility drills to improve the posterolateral and posteromedial reach. The program started with a short cardiovascular warm-up (e.g., stationary bike) for 5–8 minutes and self-myofascial techniques to address tissue density and possible trigger points. Foam rolling on the hip and upper leg muscles was performed. In sequence, two sets of 30–60 seconds of static stretching were performed for the hamstrings, quadriceps, hip rotators, and hip flexors muscles (Reiman & Matheson, 2013). The primary component of the exercise regimen encompassed dynamic stretching drills, where subjects positioned one foot at the top of a 30 cm stepper. Subsequently, they commenced movement on the contralateral foot, which rested on a cloth or a sliding pad, in both posteromedial and posterolateral directions. This routine was executed for a total of 2 sets, comprising ten repetitions in each specified direction. Also, drills were prescribed to improve dorsiflexion and increase the anterior reach. At first, the subjects would use a massage stick for self-myofascial release in the calf and plantar fascia before stretching the calf muscle for two sets of 30–60 seconds. The primary exercise involved ankle dorsiflexion while in a half-kneeling position and with a dowel positioned on the exterior of the front foot. In this position, the subjects were instructed to incline forward and push their knee towards the outer side of the dowel. It was emphasized to keep the heel of the leading foot in contact with the ground throughout the movement. Based on the recommendations of Campa *et al*. (2018), the subjects were instructed to perform the drill in two sets of 20 seconds, with a brief five-second rest interval between them. Following the suggestions of Thomas *et al*. (2018), it was advised to perform the corrective program after the clay shooting training or during 'non-shooting' days five times per week.

2.3.4. Hand Grip Strength

Following the assessment of hand grip strength for both hands, the strength training program emphasized enhancing grip strength in the weaker hand. The subjects were instructed to incorporate grippers with varying resistance levels (i.e., 20, 40, 60, 80 kg) tailored to their needs. The recommended protocol involved engaging in resistance exercises 3 to 4 times a week, allowing at least 48 hours of rest for proper muscle recovery. Based on the recommendations of Carpinelli and Otto (1998), participants were instructed to perform grip training with three sets of 5–8 slow repetitions and a 3-minute recovery period between sets. This lower repetition range was chosen for its effectiveness and safety in engaging more muscle fibers and promoting optimal strength development (Carpinelli & Otto, 1998).

Additionally, subjects were encouraged to use their weaker hands more during daily activities (e.g., carrying bags, opening doors, moving objects).

3. Results

The statistical analysis for this study was conducted using SPSS v25.0 (SPSS Inc., Chicago). Before the analysis, the data underwent normality testing using the Shapiro-Wilk test at a significance level of $\alpha = 0.05$. Homogeneity of variance was confirmed using Brown and Forsythe's test. To examine the differences in shooting scores and fitness characteristics between the intervention and control groups, independent-sample t-tests were used with a significance level of $p < 0.05$. Cohen's (1992) was used to determine effect sizes, and 95% confidence intervals were calculated for each comparison. Participants were reassessed after six weeks, and the intervention group showed significant improvements in bilateral grip asymmetry and YBT-QL reach.

Additionally, there were significant improvements in the YBT-LQ composition score and the sum in single-leg balance. Most importantly, the intervention group significantly improved their average shooting score, while no significant results were found in the control group. Results from the independent-sample t-test found significant differences in the intervention group for average shooting score ($t(31) = 4.46$, $p < 0.001$), the difference in bilateral grip strength ($t(31) = -2.68$, $p = 0.012$), the

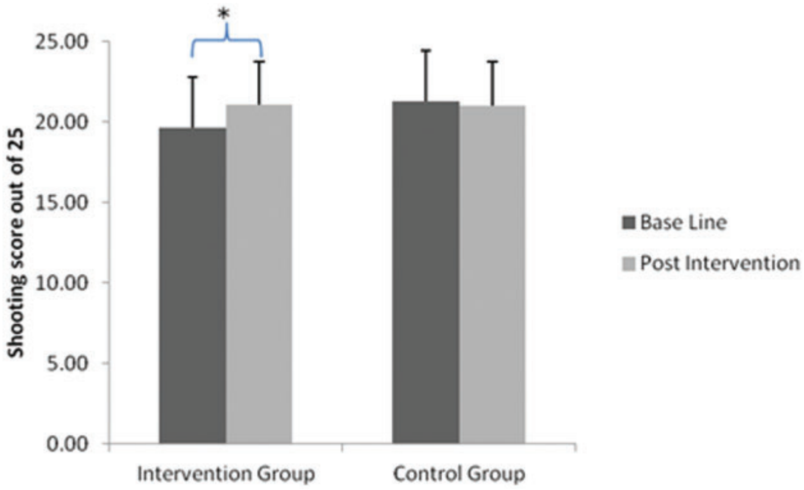

Fig. 1. Average training shooting score (per round of 25 shoots) base line and post-intervention results showing significant differences in the intervention group. *denotes $p < 0.001$.

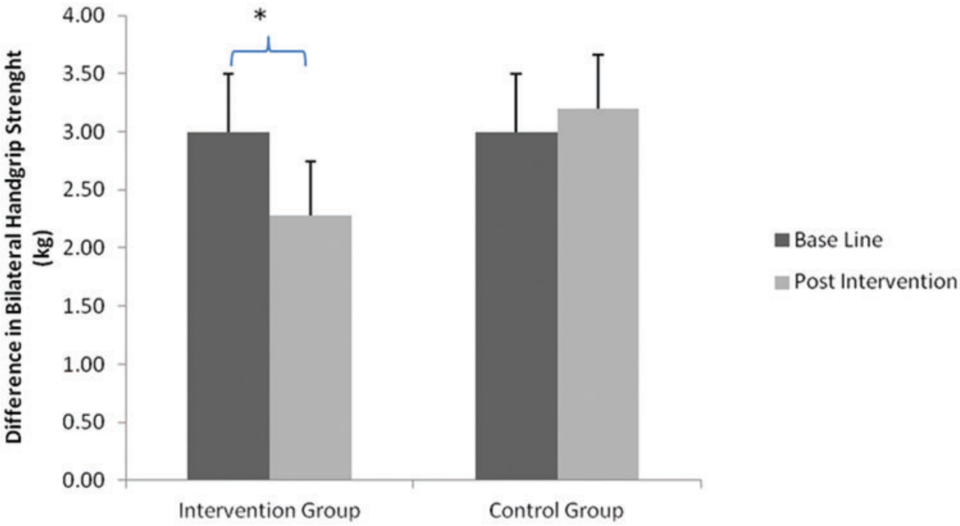

Fig. 2. Average difference in bilateral grip strength (kg) base line and post-intervention results showing significant differences in the intervention group. *denotes $p = 0.012$.

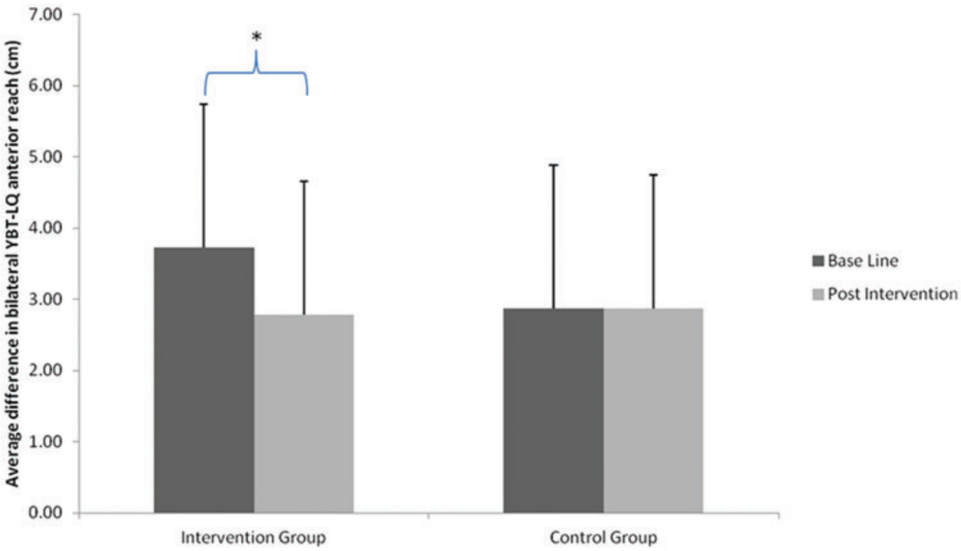

Fig. 3. Average difference in bilateral YBT-LQ anterior reach (cm) base line and post-intervention results showing significant differences in the intervention group. *denotes $p = 0.036$.

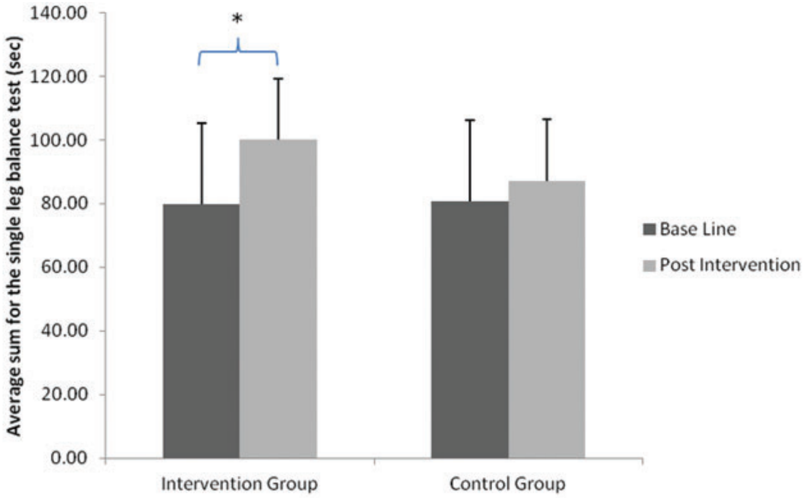

Fig. 4. Average sum for the single leg balance test (sec) base line and post-intervention results showing significant differences in the intervention group. *denotes $p = 0.027$.

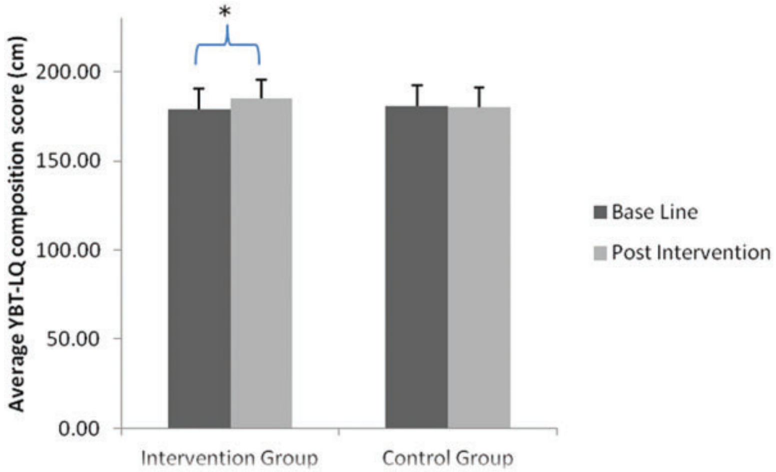

Fig. 5. Average YBT-LQ composition score (cm) base line and post-intervention results showing significant differences in the intervention group. *denotes $p < 0.001$.

YBT-LQ anterior reach ($t(31) = -2.20$, $p = 0.036$), the sum for the single leg balance test ($t(31) = 2.32$, $p = 0.027$), and the YBT-LQ composition score ($t(31) = 4.17$, $p < 0.001$) (Figs. 1–5). After six weeks of follow-up for the remaining 17 subjects, a 3 × 2 factorial ANOVA revealed no further significant improvement in performance for any group.

4. Discussion

The present study was a prospective controlled trial to assess the effects of an asymmetry correction program on Skeet and Trap shooting athletes. The individual programs were designed to reduce asymmetries and purported to improve performance. The review study by Maloney (2019) provides empirical evidence from various sports where certain variables' imbalances negatively correlate with markers of athletic performance (e.g., sprinting time, jump height). Further, the same author concludes that correcting asymmetry can improve performance and minimize injuries. To our knowledge, no studies demonstrate an improvement in shooting accuracy after correcting body imbalances. Thus, this study represents a pioneering effort to implement an intervention program focused on improving detected asymmetries by following personalized exercise regimes in the context of Olympic Clay shooting.

The findings of this study are unique, and there is compelling evidence that after the six-week intervention period, there is a significant improvement in the mean shooting score within the group subjected to the intervention. Besides better shooting accuracy, the same participants improved significantly handgrip strength symmetry, which confirms the findings of Peljha *et al.* (2021) that clay shooters with smaller bilateral grip asymmetry perform better.

The present investigation yields findings about the augmentation of three additional parameters of paramount significance. Specifically, significant enhancements have been observed in single-leg balance, bilateral anterior reach symmetry, and the comprehensive total composition score within the context of the YBT-LQ. While bipedal balance and postural control were examined in the past (Peljha *et al*., 2021; Puglisi *et al*., 2014), no such empirical evidence exists on single-leg balance. Certainly, a better single-foot balance emerges as an essential fitness parameter for clay shooters, positively impacting their overall performance. Furthermore, the apparent enhancement in the composition score of the YBT-LQ underscores a convincing correlation between improved lower body mobility and better performance outcomes.

A compelling conclusion can be drawn: the initial six-week intervention led to obvious enhancement across the abovementioned parameters and improved shooting scores. Nonetheless, the intricate interplay of these factors necessitates further empirical inquiry to identify whether a specific parameter or a combination of them resulted in better shooting accuracy. In addition, it is vital to underscore that the six-week follow-up period with the remaining 17 subjects showed no further noteworthy improvements in shooting performance. These empirical findings imply the decisive impact of the initial corrective program on performance, but conversely, the further intervention did not have the same tendency. The reason for the immediate success of an initial corrective program can be attributed to the neuromuscular adaptations it causes. These adaptations include enhanced motor control, coordination, and muscle activation patterns, as Folland and Williams (2007) noted. Furthermore, Vealey (2007) supported the idea that the accomplishment of an initial corrective program can boost an athlete's confidence and motivation, leading to better performance. However, a plateau effect tends to occur where the initial corrective program addresses the most significant issues, leaving fewer areas for improvement, which can limit the effectiveness of further interventions, according to Gelman *et al*. (2022).

Nonetheless, our findings confirm previous work that demonstrated the negative impact of bilateral asymmetries on Olympic clay shooting performance (Peljha *et al*., 2021) and that reducing the imbalances positively affects shooting accuracy in Olympic clay shooters. Similar evidence exists for other sports with high demands for fine motor skills. For instance, special programs for improving flexibility and correcting muscle asymmetries created by repetitive movements were proven beneficial for injury prevention and performance enhancement in golf (Zouzias *et al*., 2018). Based on Guiard (1987), bilateral symmetry is a mirror deviation across the corona axis. Motor tasks are classified into unilateral, bilateral asymmetric, out-of-phase bilateral symmetric, and in-phase bilateral symmetric. This classification puts clay shooting, golf, and other unilateral sports into the second category. The asymmetric body positioning and action during clay shooting could be best compared with that of a golf player when performing a swing with rotational movements around the vertical axis. Additionally, both activities highly demand eye-hand coordination and complex sensory-motor skills (DeBroff, 2018). In both sports, the motion consists of a dynamic body rotation around the vertical axis by leading the movement with the non-dominant hand and with a similar stress distribution to the musculoskeletal system. However, in clay shooting, the action is performed without a further shoulder, elbow, or wrist flexion, yet with an additional unilateral impact from the gun's recoil. It is argued that if such asymmetries in mechanical loading are repeated over long periods and left uncompensated, a unilateral dominance could be created (Leveau & Bernhardt, 1984). Such disparity could further shorten the involved muscle tissue and negatively impact joint mobility (Kalata *et al*., 2020). In addition, Pion *et al*. (2015) suggested that a higher level of performance would result in greater development of sport-specific physiological and motor characteristics. Moreover, Vad *et al*. (2004) concluded that morphological and functional asymmetries will develop somewhat due to specific physical stress, even if the training is carried out correctly. Furthermore, various studies report that muscle strength and morphology asymmetries can negatively affect performance (Grygorowicz *et al*., 2010; Risberg *et al*., 2018; Stastny *et al*., 2017; Vargas *et al*., 2019).

However, the present study suggests that such improvements have been shown to be effective in the first instance but not when continued for an extended period. It could be assumed that the early neuro-muscular improvements in symmetry have the most impact on performance and that those levels should be maintained and regularly assessed as part of the performance optimization process.

While this study provides valuable insights, the relatively small sample size calls for further research with a larger cohort to enhance the generalizability of the findings and further exploration of specialized training protocols, utilizing the latest technologies in future research. For instance, prospective studies should be encouraged to incorporate EMG measurements to establish more precisely the impact of neuromuscular asymmetries on muscle contractions and, ultimately, shooting efficiency. This methodology was utilized by Svecova and Vala (2018), revealing a significant correlation between muscle contractions and shooting accuracy in air rifle athletes. The authors further suggest that using EMG to assess shooting athletes would identify performance errors caused by incorrect muscle tension and provide a better insight into the shooter's physical condition.

In summary, this pioneering prospective controlled trial underscores the importance of addressing asymmetries in training routines. It emphasizes the need for continued assessment and maintenance of symmetry levels for optimizing shooting accuracy. At the same time, future research with larger cohorts and advanced technologies like EMG measurements is recommended to explore strategies for further enhancing athletic achievement in Olympic clay shooting.

5. Conclusion

This prospective controlled trial represents a pioneering effort in Olympic Clay shooting to address asymmetry-related issues in Skeet and Trap shooting athletes. Similar to empirical evidence from other sports, our study demonstrated the effectiveness of an asymmetry correction program in enhancing shooting performance and reducing imbalances. The significant improvement in shooting scores, handgrip strength symmetry, single leg balance, and lower body mobility within the intervention group underscores the positive impact of targeted interventions on shooting accuracy and overall athletic performance.

Our findings align with existing research, highlighting the negative correlation between bilateral asymmetries and shooting performance. After the six-week intervention, the initial results emphasize addressing asymmetries in Olympic clay shooting. However, the lack of continued improvement during the extended follow-up period suggests that early neuro-muscular enhancements might be more beneficial for performance gains. Nevertheless, the program's continuation is recommended as this could serve as maintenance of the initial gains. This underscores the need to regulary assess and sustain symmetry levels to optimize shooting performance, which is related to bilateral symmetry of handgrip strength, ankle and hip mobility, single-leg stability, and overall lower-body mobility.

We recommend incorporating regular assessments of these parameters into training routines and implementing personalized corrective programs. The correlation between asymmetry corrections and shooting accuracy demonstrated in this study gives a base for further exploring strategies for enhancing athletic achievement in this sport.

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Conflict of Interest

The authors declare that there are no competing interests.

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