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Original Article

Assessment of physical fitness parameters in Olympic clay target shooters and their relationship with shooting performance

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Abstract:
Problem Statement: There is an noticable absence of scientific research on the role of certain physical fitness parameters in Olympic clay target shooting. Purpose: The objective of this exploratory study was to identify the relationships between selected anthropometric and fitness parameters with shooting performance of Olympic clay target shooters and any differences based on skill level. Approach: Nineteen Cyprus shooting federation members of beginner (n = 11) and national-level (n = 8) abilities for both skeet and trap participated. Shooting results were tested for association with anthropometrics, reaction time, balance, posterior muscle chain flexibility, shoulder mobility, grip strength, upper-body strength endurance, trunk flexion/extension strength and cardiopulmonary fitness. Results: Bivariate Pearson's correlation coefficient tests showed significant, strong and moderate correlations between shooting performance and bilateral symmetry in shoulder mobility (r = 0.80, p < 0.001) and handgrip strength (r = 0.61, p = 0.01). When accounting for skill level, elites demonstrated significant differences in height ($t_{(17)}$ = −2.76, p = 0.01; d = 1.29, 95% CIs [172, 178]), mass ($t_{(17)}$ = −2.47, p = 0.03; d = 1.85, 95% CI [68.7, 87.1]), posterior muscle chain flexibility ($t_{(17)}$ = 4.46, p < 0.001; d = 2.04, 95% CI [25.2, 33]), dynamic ($t_{(17)}$ = 3.09, p = 0.01; d = 1.43, 95% CI [31.1, 38.7]) and static balance ($t_{(17)}$ = 0.3, p = 0.01; d = 1.35, 95% CI [41.5, 59.9]). Conclusions: These findings suggest that specific prerequisites may be associated with and, in fact, support being elite. Furthermore, that increasing upper-body symmetries could improve shooting score. As such, this study provides the first empirical evidence across a range of fitness parameters for Olympic clay shooting.
Key Words: Bilateral asymmetry, Clay target shooting, Skeet, Strength and conditioning, Trap

Introduction

Competition in high-performance sports is extremely tough and within all disciplines, including clay target shooting, coaches and experts from various support disciplines endeavour to help elite performers toward higher scores (Causer, Bennett, Holmes, Janelle, & Williams, 2010; Puglisi et al., 2014). To this end, new technologies are capable of dissecting skills into subcomponents for improved technical understanding (Swanton, 2016). Importantly, however, Hawley and Burke (1998) identified that competitive shooters must also be physically well trained to optimise skill execution. Despite these assertions, however, recommendations regarding the importance of specific physical fitness parameters in clay shooting are very limited (cf. Peljha, Michaelides, & Collins, 2018). Therefore, there is a need to focus on these aspects in order to examine their performance enhancing potential.

Although clay shooting might appear non-strenuous, such events represent an effortful workload for athletes. Notably, the combination of competitive pressure, format and duration can place considerable demand on shooters' physical fitness (Mon-López, Moreira da Silva, Morales , López-Torres & Calvo, 2019). When executing, the shooter must repetitively perform a dynamic movement with precision while holding the shotgun which weighs approximately 4 kg. Despite a short-duration action, there are many shots. Typically, competition rounds last between 15–20 min with a 1 hr break between each of five rounds spread across 2 or 3 days. In short, it is likely that clay shooting would benefit from a fitness revolution in much the same way that other target-based sports have experienced in recent times (Hellström, 2017). Consequently, understanding how to manage and optimise this challenge is a key role for the physical conditioning coach.

In the Olympic disciplines of skeet and trap, participants shoot saucer-shaped clay targets launched from a spring device called a trap. At official competitions, the number of shots totals 125; completed across 5 rounds of 25. Competition finals consist of 60 additional targets in skeet and 50 in trap for the top two competitors. In skeet, targets are launched from two "houses" (high and low) diagonally across and away from the shooter (Figure 1A). Specifically, for Station 1 the athlete loads the gun with one cartridge, prepares and then calls for the target from the high house which is thrown within a period of between 0.2–3 s. Following this, the athlete loads with two cartridges, prepares, calls and shoots at a double (one from each house). This repeats

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at Stations 2 and 3, followed by two singles at Station 4, a single and a double at Stations 5 and 6, one double at Station 7, two doubles back at Station 4 and finally, two singles from Station 8. All shots must also be executed before the targets pass the last flag within the shooting range (ISSF, n.d.). In trap, there is a single trap house located 15 m in front of the shooter (Figure 2B). One clay target is launched into the air away from the shooter at varying unknown angles from nine possible defined schemes. Two shots may be fired at each target, on all five firing stations, until five rounds are completed (ISSF, n.d.).

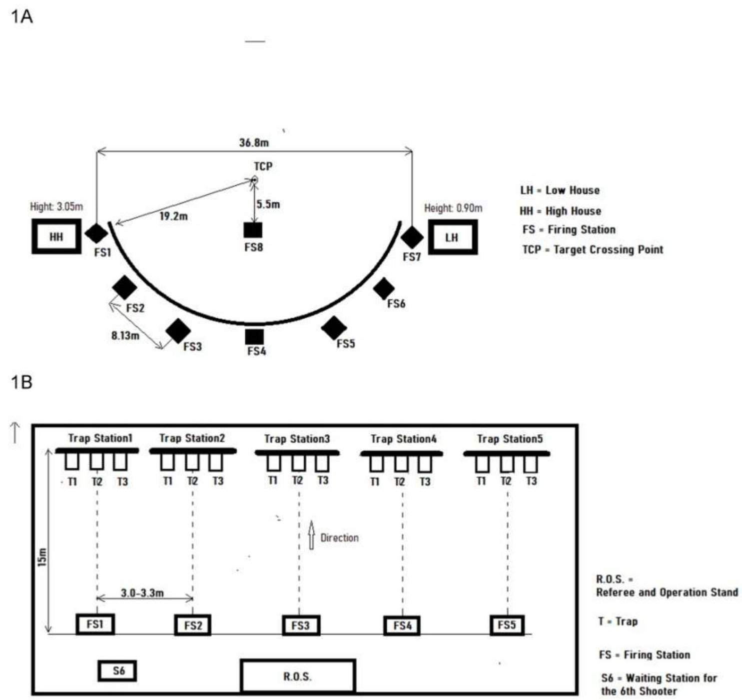

Figure 1. Layout of a skeet shooting field (A) and layout of a trap shooting field (B).

As already identified, however, there is a significant dearth of research to inform best practice in these events. Indeed, a systematic review by Peljha et al. (2018) found only one study in this domain for clay target shooting. In the one study they reported greater postural stability (i.e., balance) to be a characteristic of elite compared to lesser-skilled shooters (Puglisi et al., 2014). However, a key limitation of this study was the lack of exploration beyond measures concerning this factor. As such, there remains significant need to investigate additional physical fitness parameters that may be associated with shooting success.

Reflecting other related shooting disciplines, research has identified several physical fitness parameters that are associated with success. Kayihan, Ersöz, Özkan, and Koz (2013) found significant positive but very weak/weak correlations for balance (r = 0.31), flexibility of the posterior muscle chain (r = 0.18) and handgrip strength (r = 0.24) with pistol shooting performance amongst Turkish Police Academy cadets. Other investigations have sought to demonstrate or infer causation. Following an intervention programme for pistol and rifle shooters, Krasilshchikov, Zuraidee, and Singh (2007) concluded that increased core strength, along with improved balance, resulted in better aiming capacity which was suggested to be directly related to performance outcome. Further, the comparative study by Mondal, Majumdar, and Pal (2011) revealed that, while VO_2 max values' of Indian rifle shooters were lower than international standards in basketball, soccer, running and swimming, they were similar to those in shot put, discus and weightlifting; in other words, placing them in a category distinct from the general population. Despite these suggestive findings, however, no empirical evidence exists on the importance of these, or other, fitness parameters, which could contribute to meeting the notably dynamic executional and endurance demands in trap and skeet shooting.

Finally, while many studies in sport science (e.g., Puglisi et al., 2014; Goonetilleke, Errol, Hoffmann, & Lau, 2009; Era, Konttinen, Mehto, Saarela, & Lyytinen, 1996) have focused on exploring expert–novice differences, there has been little consideration that significantly different variables might result from being elite but not associated with performance. In other words, a minimum threshold for some variables might be necessary to maintain elite status but, further development of these will not improve performance, what we call 'hygiene factors' (Herzberg, Mausner, & Snyderman, 1959). In contrast, an increase in 'performance factors' *would* lead to an increase in performance. Accordingly, searching for differences between groups might be somewhat informative but not be the most optimal approach. Therefore, the purpose of this exploratory study was to identify both performance and hygiene factors associated with clay shooting success. Specifically, we were interested in (a) which physical fitness parameters, if any, identified by previous literature as being of potential interest within the sport[5] correlate with current shooting scores, as well as (b) which parameters, if any, can discriminate based on skill level in the Olympic disciplines. Based on previous research in other shooting disciplines, we hypothesised that certain selected parameters would show significant correlations with the shooting performance and, that some parameters would differ between elite and non-elite shooters

Material & Methods

Participants

Nineteen right-handed members (3 females, 16 males; M_{age} = 28.7 years, *SD* = 11.3) of the Cyprus Shooting Federation competing in the Olympic disciplines of skeet (*n* = 9) and trap (*n* = 10) volunteered for this exploratory study. Performance level ranged from non-elites (*n* = 11; $M_{experience}$ = 3.7 years, *SD* = 3.4) with a shooting score average of 100.1 (*SD* = 11.9) from the last three competitions, to elite members of the Cyprus national team (*n* = 8; $M_{experience}$ = 7.1 years, *SD* = 4.8) with a shooting score average of 112.9 (*SD* = 2.6) from the last three competitions. Four members of the elite group reported working with a physical fitness coach.
Participants read an information sheet and provided signed informed consent before the investigation. For shooters under the age of 18 years, assent was provided in addition to parental consent. The investigation was approved by the university's ethics committee (BAHSS518) in accordance with the Declaration of Helsinki's ethical principles for research involving human participants prior to conducting the study.

Procedure

Each participant was tested across all parameters within one session lasting approximately two hours. Firstly, the three most recent competitive shooting scores and anthropometric measurements were recorded. Following this, reaction time, balance (postural stability), flexibility of the posterior muscle chain, shoulder mobility, handgrip strength, upper-body strength endurance, trunk strength and cardiopulmonary fitness were examined in this order to avoid fatigue impacting across the tests.

Shooting scores and anthropometrics. Participants confirmed their last three official shooting results. After this, height, mass and body fat composition using a single frequency Body Fat Analyzer (BF-322, Tanita Corporation of America, Inc., USA) were measured. Procedures for this latter test were conducted following the instructor's manual.

Reaction time. Reaction time to a visual stimulus was measured using an Optojump laser system (Microgate, Italy), imitating the action during competitive shooting. After individually adjusting the height of the Optojump system, participants' unloaded shotgun was positioned inside the laser beams. A laptop was placed 3 m in front (Figure 2). As soon as the colour of the monitor changed to green, the participant moved the gun at will in any direction, as if shooting real clay discs. For the skeet shooters, nine trials were used with a 60 s break in between. For the trap shooters, 25 trials with a 30 s break were used. Differences in trials and intervals reflect a representative course of shooting, both in the number of shots and time required to move between stations in skeet (see earlier explanation of shooting format). Average reaction time scored across all trials was used for analysis. Two of the non-elite group did not complete this final test due to technical issues.

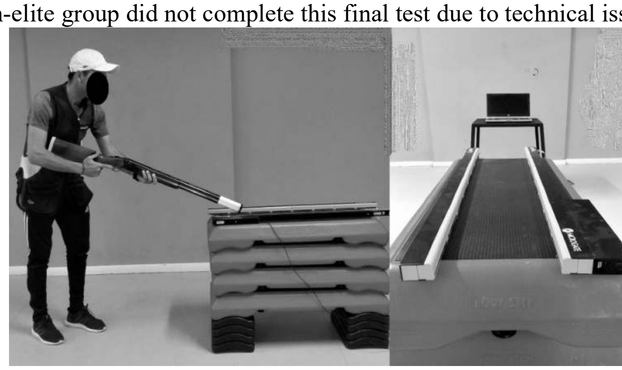

Figure 2. Participant setup with shotgun positioned between the Optojump system prior to trial commencement (left). Optojump system positioned in line with the stimulus screen (right).

Balance (Postural Stability). Wearing the same shoes as during training/competition, participants faced a screen while standing on a disc which was free to move in all directions, with their arms by their side (Figure 3). Coordi software (MFT Challenge disc, TST Trendsport, Austria) provided immediate feedback about the position of the disc, represented by a dot (Hildebrandt, Müller, Zisch, Huber, Fink, & Raschner, 2015). Following a familiarisation period of 5 min, participants were instructed to keep the small dot inside the bigger dot (Figure 3). To test for dynamic balance, the bigger dot moved in all directions and participants had to move the smaller dot accordingly by shifting their centre of mass. To assess static balance, participants had to keep the dot stationary in the middle of the screen inside the bigger dot for 15 s (software programme Level 3). The total scores from a potential of 100 points were recorded for static and dynamic balance, respectively.

Figure 3. Positioning of the participant on the MFT Challenge disc (left). Screen showing the small dot which should be moved by the participant in the big (darker) dot by shifting the weight on the board (right).

Posterior muscle chain flexibility. The sit-and-reach test was used to obtain flexibility measurements for lower back and hamstring muscles. A 32.4 cm high × 53.3 cm long box with a 23 cm heel line mark was placed against the wall. Participants sat in front of the apparatus barefoot with their knees fully extended and heels placed against the edge of the box. To ensure complete leg extension the corresponding author held one hand lightly against each participant's knees. Participants placed their hands on top of each other, palms down and slowly bent forward along the measuring scale. The forward stretch was held for 1–2 s and the distance was recorded to the nearest cm. This was repeated three times with a break of 1 min between each and the best result was recorded. Test–retest reliability was reported to be $r = 0.94$ (Johnson & Nelson, 1986).

Shoulder mobility. This used the Functional Movement Screening (FMS) for shoulder mobility test (Cook, Hoogenboom, & Voight, 2014). Participants stood facing and touching the wall with their toes and were instructed to extend their arms out from the shoulders while making fists with their hands. Following this, participants were asked to perform a reciprocal reaching pattern by bringing one arm over the top (external rotation of the shoulder) and the other underneath (internal rotation). It was emphasised that once the fists had stopped moving, the participants were not allowed to move them closer together. Participants performed three repetitions on one side, with a 45 s rest between the trials, attempting to get the fists as close together as possible and then repeated this procedure on the contralateral side. The distance in cm between the two closest bony prominences of the fists in this position was measured and the best result out of the three attempts recorded. The superior arm defined the recorded side.

Handgrip strength. Handgrip dynamometry was used to assess handgrip and upper-body strength. Participants stood holding a handgrip dynamometer (Grip D, T.K.K. 5401, Takei Scientific Instruments, CO., Ltd. Japan). The gripping site was individually adjusted so that the second phalange of the hand fitted under the handle and was held between the fingers and the palm, at the base of the thumb. Participants were instructed to bend slightly forward, flex the arm slightly 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 min break between each trial to ensure physical recovery. The highest measurement for each hand was recorded. Test–retest reliability was reported to be $r = 0.90$ (Adams, 1998).

Upper-body strength endurance. Participants completed the maximum push-up test by lying face down in a prone position with the arms bent, body straight and hands flat on the floor beneath the shoulders. During the "up" position the arms had to be almost completely extended, the body rigid throughout the entire test with the back straight at all times. A 5 cm high sponge was placed on the floor for the participants to touch with their chest during the "down" position. For females the modified, "from the knees" position was used. The score recorded was the number of correct push-ups completed. No rest was allowed between push-up attempts. Test–retest reliability was reported to be $r = 0.93$ (Johnson et al., 1986).

Trunk flexion/extension strength. An isokinetic dynamometer (HUMAC/NORMTM Testing & Rehabilitation System; Computer Sports Medicine Inc., USA) was used to measure trunk flexion/extension strength. Considering the sport-specific movement of clay shooting, participants were placed on the trunk extension/flexion (TEF) modular component in a standing position with the axis of rotation set at the intersection point of the mid-axillary line and the lumbar-sacral junction (Yoo et al., 2014). The range of motion of TEF was set from −8° to 60°. Participants then performed four maximal warm-up repetitions and four maximal test repetitions at 60 °/s, followed by the same at 120 °/s. Rest time between test velocities was 60 s. Of interest from the isokinetic muscular function at 60 °/s and 120 °/s, was peak torque (PT), for trunk flexor and extensor, respectively.

Cardiopulmonary fitness. To measure the maximum capability of the body to consume oxygen, all but one of the participants (one member of the highly-skilled group could not participate due to injury) performed a VO_2 max test using an incremental treadmill (modified Heck protocol). Gas exchange measurements were collected with the Cosmed Quark cardiopulmonary exercise test system (CPET, Rome, Italy), using a breath-by-breath analysis (Nieman, Austin, Dew, & Utter, 2013). Laboratory temperature was kept constant at 22 ± 1 ºC and the relative humidity was 50%. In its entirety, the HUMAC/NORMTM Testing and Rehabilitation System protocol consisted of a warm-up, exercise and a recovery phase. During the warm-up and test phases, the inclination was kept constant at 3%. In the former, the speed started at 4.8 km/hr and increased by 1.2 km/hr every 1 min for 3 min. Whereas during the latter, speed started at 8.4 km/hr and increased by 1.2 km/hr every 2 min until exhaustion. Termination of the test was determined when the participants reached volitional exhaustion, or when the VO_2 levels remained constant or reduced with an increased workload. The recovery phase speed was reduced to 4.8 km/hr and remained constant for 3 min with no inclination. VO_2 max was detected as the highest value recorded for an average of 10 s.

Statistical analysis

Descriptive statistics (mean ± SD) were calculated for all the fitness parameters, anthropometric variables and the last three official shooting scores and subsequently analysed using SPSS v25.0 (SPSS Inc., Chicago). Data were checked for and found to be normally distributed using the Shapiro-Wilk test with the level of significance set at $p < 0.05$. Brown and Forsythe's test was used to verify the homogeneity of variance. Bivariate correlation analysis was used to compare correlations among anthropometric and fitness variables and outcome scores for the whole group. Pearson-product moment correlation coefficients were calculated for these variable scores and the mean of the last three official shooting competitions scores which consisted of 5 rounds of 25 shots. Differences in fitness/anthropometric characteristics were then compared between those participants defined earlier as elite and non-elite shooters, using independent-sample *t*-tests with the level of significance set at $p < 0.05$. Effect sizes were calculated and classified by Cohen's *d* (small = 0.2, medium = 0.5 and large = 0.8; Cohen, 1992) and 95% confidence limits were calculated for each comparison.

Results

Descriptive statistics (mean ± *SD*) by group and the entire sample are shown in Table 1 for shooting score, anthropometric data and for all tested fitness parameters.

Table 1. Shooters' Anthropometric and Fitness Test Results by Group and Overall Average.

Variables	Elites (*M* ± *SD*)	Non-Elites(*M* ± *SD*)	Overall (*M* ± *SD*)
Anthropometric Measures			
Height (cm)	170.3 ± 6.0*	178.2 ± 6.3*	174.8 ± 7.2
Mass (kg)	65.9 ± 14.5*	86.6 ± 20.2*	77.9 ± 20.5
BMI (kg/m^2)	22.5 ± 3.7	27.4 ± 6.7	25.3 ± 6.1
Body Fat (%)	18.3 ± 5.5	22.9 ± 8.6	21.0 ± 7.6
Fitness Measures			
Reaction Time (s)	0.40 ± 0.054	0.40 ± 0.034	0.40 ± 0.043
Dynamic Balance (points out of 100)	40.6 ± 7.2*	30.7 ± 6.7*	34.9 ± 8.4
Static Balance (points out of 100)	64.1 ± 16.6*	40.9 ± 17.8*	50.7 ± 20.5
Flexibility of the posterior muscle chain (cm)	36.4 ± 6.6*	23.8 ± 5.6*	29.1 ± 8.7
Left Shoulder Mobility (cm)	16 ± 4.6	21.5 ± 7.1	19.2 ± 6.7
Right Shoulder Mobility (cm)	15.8 ± 5.6	16.0 ± 7.6	15.9 ± 6.6
Difference between R/L Shoulder Mobility (cm)	2.3 ±2.5	4.6 ± 4.5	3.6 ± 3.9#
Right Handgrip (kg)	46.3 ± 12.3	48.7 ± 6.4	47.7 ± 9.1
Left Handgrip (kg)	43.2 ± 12.5	43.9 ± 6.5	43.6 ± 9.2
R/L Grip Difference (kg)	3.8 ± 2.4	4.8 ± 4.2	4.4 ± 3.5#
Max Push-up (repetitions)	28.6 ± 12.1	22.2 ± 11.6	24.9 ± 12.0
Trunk Flexion at 60 °/s (Nm)	189.5 ± 50.3	217.5 ± 39.8	205.7 ± 45.4
Trunk Extension at 60 °/s (Nm)	241.4 ± 85.0	232.2 ± 47.0	236.1 ± 63.7
Trunk Flexion at 120 °/s (Nm)	150.0 ± 48.6	155.7 ± 87.5	151.9 ± 58.3
Trunk Extension at 120 °/s (Nm)	155.7 ± 54.6	126.0 ± 65.0	145.8 ± 56.0
VO_2 max (ml/kg/min)	44.4 ± 7.9	41.2 ±11.7	42.5 ± 10.2

*Indicates a significant difference between the group scores. #Indicates a significant correlation between the variable and overall performance score.

Pearson product-moment correlation coefficients were found to be non-significant ($p > 0.05$) between height ($r = -0.19$, $p = 0.48$), mass ($r = -0.46$, $p = 0.063$), BMI ($r = -0.46$, $p = 0.062$), body fat ($r = -0.37$, $p = 0.14$), dynamic balance ($r = 0.34$, $p = 0.18$), static balance ($r = 0.12$, $p = 0.65$), posterior muscle chain flexibility ($r = 0.40$, $p = 0.11$), right shoulder mobility ($r = 0.42$, $p = 0.10$), left shoulder mobility ($r = 0.25$, $p = 0.34$), right handgrip strength ($r = -0.26$, $p = 0.32$), left handgrip strength ($r = -0.02$, $p = 0.95$), upper-body strength endurance ($r = 0.15$, $p = 0.58$), trunk flexion at 60°/s ($r = -0.41$, $p = 0.11$), trunk extension at 60°/s ($r = -0.25$, *p*

= 0.33), trunk flexion at 120°/s ($r = -0.20$, $p = 0.64$), trunk extension at 120°/s ($r = -0.32$, $p = 0.44$), cardiopulmonary fitness ($r = 0.29$, $p = 0.28$) and mean shooting score.

However, a post hoc decision to analyse tests that had not previously been reported from existing shooting literature revealed several significant and high correlations with shooting results. Greater symmetry between the right and left shoulder mobility showed a strong correlation with performance score ($r = 0.80$, $p < 0.001$). Similarly, bilateral symmetry in handgrip strength revealed a significant and strong correlation with score ($r = 0.61$, $p = 0.01$). Additionally, the two parameters examining upper-body asymmetries showed a significant moderate correlation between them ($r = 0.55$, $p = 0.02$).

Results of independent-sample *t*-tests found several differences between elite and non-elite shooters. A significant difference was observed for height ($t_{(17)} = -2.76$, $p = 0.01$; $d = 1.29$, 95% CIs [172, 178]), mass ($t_{(17)} = -2.47$, $p = 0.03$; $d = 1.85$, 95% CI [68.7, 87.1]), posterior muscle chain flexibility ($t_{(17)} = 4.46$, $p < 0.001$; $d = 2.04$, 95% CI [25.2, 33]), dynamic ($t_{(17)} = 3.09$, $p = 0.01$; $d = 1.43$, 95% CI [31.1, 38.7]) and static balance ($t_{(17)} = 0.3$, $p = 0.01$; $d = 1.35$, 95% CI [41.5, 59.9]), all with large effect sizes. Interestingly, the examination identified that elite shooters were shorter, lighter and reported better dynamic and static balance, compared to non-elite shooters.

Discussion

The purpose of this exploratory study was to identify both performance and hygiene factors associated with clay shooting success. Specifically, we were interested in (a) which physical fitness parameters, if any, identified by previous literature as being of potential interest within the sport (Peljha et al., 2018) correlate with current shooting scores, as well as (b) which parameters, if any, can discriminate based on skill level in the Olympic disciplines. The main findings were that greater symmetry between bilateral shoulder mobility and handgrip strength were correlated with higher shooting scores. Finally, height, mass, posterior muscle chain flexibility and static and dynamic balance differentiated skill level groups.

Addressing the correlational performance factors, it is interesting that the two parameters found to be significantly correlated had 1) not been investigated previously within other shooting sports and, 2) related to symmetric and not absolute values. While grip strength and finger muscular force, for example, has shown to be vital for successful pistol shooting (Mon et al, 2015; Kayihan et al., 2013; Vercruyssen, Grose, Christina, & Muller, 1989), these had minimal impact in our examination. This could be attributed to the fact that competitive pistol shooters largely rely on the dominant hand for executing the shot from a static posture, whereas clay shooters engage both hands when holding the shotgun. The fact though, that the level of bilateral symmetry has shown a significant and strong correlation to shooting performance is noteworthy and suggests that the participant sample were not deficient in strength for the task, despite their varied skill level (Mon-López, Carlos, Tejero-González, & Calero, 2019).

The evidence that better-performing Olympic clay shooters have significantly greater upper-body symmetry is promising for future developments in the sport. It is possible that flexibility and strength asymmetries can create reduced control of body movements (Grygorowicz, Kubacki, Pilis, Gieremek, & Rzepka, 2010) and have been the focus of research into other whole-body actions (e.g., Sanders, 2013). An early study by Knapik, Bauman, Jones, Harris, and Vaughan (1991) concluded that such asymmetries were importantly associated with athletic injuries. Furthermore, a recent review by Maloney (2018) deduce that in sports such as track and field, soccer and swimming, performance can be enhanced with specialised training to improve symmetries. Maloney further suggests that the weaker, deficient limb may be more responsive to training and correction (see also Daneshjoo, Rahnama, Mokhtar, & Yusof , 2013). It is empirically unknown what injuries or physical problems might be caused by asymmetry of the upper-body and so research should investigate any potential links to shooting technique, motor control and physical characteristics. Recent study has identified upper-body strength of the arms and forearms, core, abdominals, waist and shoulders as being important (Mon-López, Moreira da Silva, et al., 2019), however this study did not consider the degree of symmetry when discussing any precise mechanisms. Our study presents novel evidence in the domain of clay target shooting and an attempt to establish some baselines for further scientific development.

From an interdisciplinary perspective, asymmetry may also result from an inability to represent contralateral body segments as a coherent whole and/or in the most effective way (Carson & Collins, 2016). For example, expert dancers have improved "proprioceptive matching" for the upper-limbs compared to non-dancers, as evidenced by 1) more accurate proprioceptive representations, 2) less limb-specific proprioceptive representations and, 3) greater weighting for proprioceptive reliance with the availability of visual information, during an end-point matching task (Jola, Davis, & Haggard, 2011). Dancers' bodies are suggestively more integrated as a single, centrally-coherent representation. Accordingly, it is possible that our less-skilled participants were more reliant on visually representing the task which is a less relevant and accurate modality for integrating information about multiple skill components. Tracking the nature of representations for these upper-limb skill components may therefore enhance our understanding of performance in this context and the interaction with physical fitness parameters.

Competitive clay target shooting has unique physical characteristics and imposes unique demands on the athletes. It is not clear though, whether athletes develop these physical characteristics as a result of the specific action, or they choose the particular sport because they have acquired these distinctive characteristics. Corbin and Noble (1980) suggested that the possession of a particular type of physical fitness can improve performance in a sport or physical activity. Although previous studies in other shooting sports demonstrated correlations for some of the tested parameters with shooting scores (Peljha et al., 2018) our examination has not shown any significant relation to the performance in clay shooting, therefore it might be that many potential participants will not be inherently limited in their shooting due to their pre-existing fitness levels (Mon-López, Moreira da Silva, et al., 2019). Furthermore, readers are invited to consider those results showing significant differences in our study, against existing literature as some do seem to offer promise for future investigations (e.g., flexibility and balance), albeit that some may be spurious (e.g., height and mass) due to all females in the sample being elite.

Conclusions

Despite the novel insights that this exploratory study has provided, we recognize that it was not without limitation. Firstly, the sample size was relatively small and so the extent of generalizability to all other shooters is fairly limited. Secondly, our sample was comprised of both trap and skeet shooters which could potentially have conflating effects due to differences across techniques. Therefore, future research should seek to use this study for the development of more widespread testing within the sport of Olympic shooting and, establish any discipline-specific characteristics that may be important to success.

In conclusion, this study indicates that bilateral symmetry could play an important role in the Olympic shooting success. This information suggests that experts working with clay target shooters should design and further develop exercise programmes and methods that will improve bilateral symmetry. More focus may be given to the refinement of athletes' techniques, by establishing a good level of neuromuscular balance and flexibility in order to maintain standards of success. At the very least, experts should assess and discuss these relations to better understand the possible direct or indirect effect on the shooting performance. Future studies should particularly investigate the role of bilateral symmetry and how the physique of more successful shooters is interrelated, in order to obtain a deeper understanding of success.

Conflicts of interest - None

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