Original Article

The relative importance of selected physical fitness parameters in Olympic clay target shooting

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ABSTRACT

Purpose: To examine the current state of empirical research, theoretical explanations and applied importance of selected physical fitness parameters in Olympic clay target and related shooting disciplines. Method: Four online databases (EBSCOhost, Pub Med, Emerald Insight and Google Scholar) served as data sources for the study. Multiple combinations of key terms (e.g., shooting sport, skeet, and trap) were used to identify relevant literature in the English language meeting pre-specified search criteria. Content Analysis was used to identify 41 articles regarding the importance of fitness parameters in shooting sports. Results: The main finding was that previous studies have primarily concentrated on the stationary shooting disciplines. Only three studies were found on clay target shooting. One focused on the role of Quiet Eye (QE) duration, one on gun kinematics, and one on the role of postural stability. Within the other shooting disciplines, studies focused on establishing the role of postural stability, upper body strength, QE duration and the level of VO^2 max. Conclusion: Based on the research available with regard to the importance of physical fitness parameters in the Olympic clay target shooting disciplines, it is difficult to offer firm recommendations. In other shooting disciplines, postural stability and longer QE duration, as well as a certain level of strength, appear to be critical to successful performance. This research gap demonstrates the need to develop and expand the knowledge base within the sport. **Key words:** SHOTGUN, SKEET, TRAP.

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INTRODUCTION

Shooting sports are categorised by the target, the distance to the target and the type of firearm. The precision target disciplines, archery, pistol and rifle shooting, involve shooting at a stationary target. In contrast, shotgun shooting involves the target moving at high speed within a predefined volume. This fact alone illustrates a fundamental difference in movement patterns between the stationary and the shotgun shooting disciplines. It has yet to be shown, however, whether fitness parameters for these two disparate tasks are also different, even though such a conclusion seems face to valid.

Clay target shooting consists of shooting a firearm at special flying targets, known as clay targets or clay pigeons. The shotgun fires projectiles that contain a large number of smaller sub-projectiles called pellets (shot). Although clay target shooting has more than twenty different disciplines, most can be grouped under the main categories: *skeet, trap and sporting*. Given our interest as providers of fitness monitoring and advice to elite athletes in these disciplines, the goal of this study was to provide a complete and systematic review of existing factual evidence addressing the role of selected physical fitness parameters in Olympic clay target shooting and related shooting disciplines.

There is an evident difference between the shotgun and the precision target shooting disciplines. The pistol and rifle disciplines, as well as archery, involve shooting at a stationary target, where an exact knowledge of the target is fundamental to a successful performance (Roberts and Turnbull, 2010). In shotgun shooting, however, the target is larger in size but moves at high speed within a predefined space. In order to follow the target before and whilst executing the shot, the clay shooter has to energetically move and rotate the upper body in a unique way, placing an additional acute strain on their musculoskeletal system. Furthermore, in clay shooting, both arms are handling the gun and are unsupported, with the competitor bent slightly forward: in short, a very different stance compared to other disciplines. Taken together, these factors suggest an essential difference regarding the movement patterns, as well as some physical parameters crucial for successful performance in shotgun shooting, compared with the rifle and pistol disciplines. There is, however, a need to elucidate this difference.

One way to accomplish this is through the use of a systematic review. Based on Liberati et al. (2009), a systematic review tries to collect all empirical facts that fits pre-specified eligibility criteria to answer a specific research question. Accordingly, the questions addressed in the current study were:

- What is the current state of published research on the importance of selected physical fitness parameters in Olympic clay target?
- What research was conducted in related shooting disciplines regarding the role of selected physical fitness parameters?
- Which studies from other disciplines could have a pertinent transfer to clay shooting?

METHOD

As stated by Hawley and Burke (1998), as with any other athletic effort, competitive shooters must be trained and conditioned physically. Reflecting the arguments presented above, we reviewed the current literature in an attempt, to sum up the data regarding the importance of selected physical fitness parameters in clay target and related shooting disciplines. The four basic online databases used were EBSCOhost, PubMed, Emerald insight and Google Scholar, using combinations of the keywords for articles, “clay target shooting,” “shooting sports,” “skeet,” “trap,” “pistol,” “rifle,” “postural balance,” “strength,” “eye-hand coordination”, that identified the importance of selected physical fitness parameters in these shooting sports. Additional search items were

then incorporated, based on key terms discovered in the titles, abstracts, and full texts of the records yielded from the initial search. We included reports that firstly, were published in English and secondly, specifically examined physical fitness parameters in shooting sports.

In total, 41 records regarding physical fitness parameters in shooting sports were identified for review. Notably, however, only three were specifically related to clay target shooting. Therefore, given this dearth of specific evidence, we decided to review the papers regarding other shooting disciplines as well. Accordingly, the Results section below demonstrates studies that addressed all the shooting disciplines, structured under the four main topics which emerged. Finally, any clay target-specific papers are listed, with any contrasts or contradictions to the main body of the literature then highlighted.

RESULTS

The presented study was focused on examining, via a systematic review, the recommendations authors have forwarded regarding the importance of selected physical fitness parameters in the Olympic clay target shooting events, trap and skeet. The initial comprehensive literature review focused on clay target shooting revealed that there was a large volume of studies irrelevant to our purpose. For example, examining the environmental influence of lead pollution and the impact of the clay targets on the ecology at a shooting range (Baer et al., 1995; McTee et al., 2016; Migliorini et al., 2004; Rooney and McLaren, 2000; Sorvari et al., 2006; Vyas et al., 2000).

Indeed, our review has indicated only one study by Puglisi et al. (2014), focusing on the relationship between good balance and better performance in the skeet shooting discipline. They observed a significantly better posture in elite shooters, compared to less good shooters, and concluded that good balance has a positive correlation to performance. These authors further recommend adding balance training to other event-specific activities, such as the improvement of anaerobic capacity and capacity for dependent motor control. In another clay target-specific work, Causer et al. (2010) analysed the quiet eye duration and the gun barrel kinematics in skeet, trap and double trap events. In addition, Swanton (2011) explored the kinematics of gun movement during trap shooting. So as one of the clearest results to emerge, we would highlight a lack of work focused in this area.

Pertinent transfer from studies in other disciplines

Despite this dearth of specific investigation in clay target shooting, however there is *some* pertinent empirical work on physical fitness parameters in other shooting disciplines i.e. pistol, rifle and archery. The four areas of focus of the examined studies were:

1. **Postural stability**, with 26 studies focusing on stationary shooting disciplines and 1 on clay target shooting.
2. **Strength**, with 10 studies focusing on pistol and rifle shooting, were several recommendations combined focuses on postural stability and strength, as well as, strength and selected anthropometric characteristics.
3. **Quiet eye duration**, with one study focusing on Olympic clay target shooting and two on rifle shooting.
4. **Maximal oxygen consumption (VO^2max),** with one comparative study discussing the VO^2max values of rifle shooters. Descriptions of each area of focus are provided in the following subsections.

Postural stability

In biomechanics, balance is defined as an ability to maintain the line of gravity (vertical line from the centre of mass) of a body within the base of support with minimal postural sway (Shumway-Coo and Haller, *1988*). Core stability (which involves static contractions of muscles of the trunk) and balance (where reflexive actions of muscles in the lower body and core are required) are significant factors for minimising the body sway observed in a static position (Anderson and Plecas, 2000).

After the pioneer study by *Spaeth and Dunham (1921),* where a strong positive correlation between steadiness and marksmanship was suggested, many other authors came to the same conclusion. Current studies in the shooting sports demonstrate that, unsurprisingly, balance, postural stability and the stability of the rifle/pistol, contribute to an increased shooting accuracy (Aalto et al., 1990; Ball et al., Wrigle, 2003; Bayati et al., 2016; Goonetilleke et al., 2009; Gulbinskienė and Skarbalius, 2009; Heimer et al., 1985; Kayihan et al., 2013; Koley and Gupta, 2012; Koley and Uppal, 2016; Konttinen et al., 1998; Konttinen et al., 1999; Mason et al., 1989; Mononen et al., 2007; Niinimaa and McAvoy, 1983; Pryimakov et al., 2015; Puglisi et al., 2014; Sattlecker et al., 2014; Stambolieva et al., 2015; Su et al., 2000; Zatsiorsky and Aktov, 1990). In the only published study on clay target shooting by Puglisi et al. (2014), the authors conclude that a good balance has a positive correlation to shooting performance in the skeet discipline. Furthermore, the authors recommend specific training for improving balance.

However, previous findings were contradicted by a recent experiment of Ihalainen et al. (2015). They reported that, in air rifle shooting, the effect of postural balance on performance was relatively small. This conclusion is supported by other authors, who also argue that shooting performance is not affected by postural stability (Anderson and Plecas, 2000; Era et al., 1996; Zemkova, 2013). In addition, Stuart and Atha (1990) reveal that, at the top performance levels, postural stability may not be the main reason that differentiates the elite from the less expert archer.

Strength

There are only a few studies in the literature that focus on muscular factors or the physical fitness of the shooter to performance. Several types of research have examined the correlation between the shoulder and forearm muscular control and the ability to stabilize the pistol (Mon et al., 2015; Pellegrini and Schena, 2005; Tang et al., 2008; Vercruyssen et al., 1988). In the study of Vercruyssen et al. (1988), a very brief and intense grip and shoulder strength-training program applied on pistol shooters reports robust strength-performance correlations. Individual subject analysis has shown that those that improved in strength also improved in shooting skill. In a more recent study by Mon et al. (2015), significant correlations between performance and finger muscular force in competitive pistol shooters were found. However, their findings disagree with the study of Vercruyssen et al. regarding the relationship between performance and shoulder abduction force. Also, no significant correlation was established between performance and height, weight, age or body mass index (BMI). Furthermore, after analysing an intervention program on 14 competitive shooters, Krasilshchikov et al. (2007) conclude that increased balance reduced swaying, and along with increased core strength improved aiming capacity. In a different study by Kayihan et al. (2013), members of the Turkish Police Academy were investigated for the relationship between efficiency in pistol shooting and selected physical fitness parameters. Results demonstrated that, along with coordination, balance and flexibility (of the posterior muscle chain), a considerable correlation between handgrip strength and the shooting performance was found. In addition, and according to a study by Koley and Gupta (2012), dominant right handgrip strength in pistol shooters had positive correlations with height, weight and upper arm circumference in contraction. In the study of Evans et al. (2003), the effect of upper extremity muscle fatigue on shooting with a rifle in an unsupported, standing firing position was assessed. The authors provide evidence that fit soldiers have a

faster recovery of shooting accuracy after intensive upper body exercises. Similar results were found regarding the effect of aerobic exercise on rifle shooting accuracy and it was concluded that soldiers with a higher level of physical fitness can quickly recover shooting accuracy following intense exercise (Ito et al., 2000). In addition, it is suggested by Hoffman et al. (1992) that the intensity of physical exertion immediately prior to biathlon shooting, affects shooting in the standing position, by influencing the stability of hold, but has a small affect on prone shooting performance.

Hypothetically, the Clay shooter needs isometric strength for keeping steady stance and body position. Additionally, a rotation of the upper body, involving muscles of the legs and trunk, is needed for following the target before executing the shot. It could be assumed that this dynamic action puts further a strain on the muscular system of the skeet and trap shooter. Also, both arms which are holding the gun are unsupported and additional static strength of the shoulder girdle and the arm flexors is required. Furthermore, the specific stance and body position should be taken into consideration. In competitive shotgun shooting, the athlete bends his upper body forward as he follows the target before the execution of the shot. In this position, the athlete or shooter places slightly more pressure on the foot in front (approx. 60%); what presumptively puts an additional strain on the posterior muscle chain.

Quiet Eye

The Quiet Eye (QE) is defined as the final fixation gaze to a target before the initiation of a planned motor response and reflects a critical period of cognitive processing during which the control parameters of a motor skill are programmed (Vickers, 1996). As stated by Behan and Wilson (2008), the accuracy of aiming is influenced by the duration of the QE period, with longer QE periods being associated with better performance. This is consistent with the findings of Causer et al. (2010), which showed that longer QE duration during skeet, trap, and double trap shooting has a positive correlation to a successful shooting performance. Further studies indicate that gaze behaviour and the QE are influenced by the level of anxiety of the performers, leading to inefficient search strategies and less efficient gun motion (Causer et al., 2010; Nian-Hong, 2003; Janelle, 2002).

Various authors (Antunes et al., 2005; Cox et al., 2003; O'connor et al., 1991; Petruzzello et al., 1991; Raglin and Morgan, 1987) have examined the relationship between maximal oxygen uptake (VO^2 max) and the reduction of anxiety. VO^2 max was defined by Hill and Lupton (1923), as the oxygen uptake attained during maximal exercise intensity that could not be increased despite further increases in exercise workload. The previous studies have observed a positive correlation between higher VO^2 max and lower stress levels. This led to the conclusion that the reduction of anxiety through higher levels of VO^2 max, or activities such as swimming and yoga (Berger and Owen, 1988), could have a positive relationship to longer QE duration and hypothetically to a more efficient shooting performance.

VO^2 max

Literature reviews have indicated only one comparative study of Mondal et al., (2011), which reveals that maximal oxygen consumption (VO^2 max) values' of rifle shooters are lower than international standards for VO^2 max of swimmers, runners, footballers, basketball and soccer players, but are very close to that of weight lifters, shot putters and discus throwers. This probably results from the fact that shooting is not considered an endurance sport (Kasapis and Thompson, 2009), and that a medium level of VO^2 max is satisfactory for a successful performance. Interestingly, the study of Wells et al. (2009), suggests that in another "non-endurance" sport (Kasapis and Thompson, 2009), the golfers with the best aerobic conditioning where those, who have shown better performance. Further, Mondal, et al. (2011) also found that female shooters have significantly higher anaerobic power values in comparison to their non-athlete counterparts. In contrast, male

shooters have lower anaerobic power values in comparison to the non-athletes. Hypothetically, the difference in anaerobic power values between the genders could be explained by the ratio of the shotgun weight to the athlete's body weight. It could be assumed that, in comparison to their male colleagues, the majority of female athletes have to put a more muscular effort in order to hold and move the shotgun, and so need higher anaerobic power values.

Although there is no existing empirical evidence in the field of the shooting sport to suggest that the level of VO^2 max could have a positive impact on the shooting result through the reduction of stress and anxiety, other studies have shown the positive correlation between higher levels of VO^2 max and lower stress and anxiety levels. For instance, Petruzzello et al. (1991) claim that the aerobic forms of physical exercises are associated with reductions in anxiety. Also, Raglin and Morgan (1987) argue that rest and exercises have similar effects on reducing state anxiety and blood pressure. However, the exercise-induced anti-anxiety effect endured for a longer period. In a more recent study, the data of Antunes et al. (2005), suggest that an aerobic exercise program has a positive correlation to anxiety and depression and indicates improvement in life quality in older individuals. In an earlier study, Dustman et al. (1984) report a remarkably better performance on diverse neuropsychological tasks of inactive seniors, after following an aerobic exercise program for four months. In conclusion, they suggest that the cerebral metabolic activity was improved through the implemented aerobic training and that this positively affected the neuropsychological performance of the group. Thus the aerobic type of training may decrease anxiety and affect positively the shooting accuracy.

Additional studies

In addition, other research in shooting sport has little or no possible transfer to the Clay shooting. For example, the study by Lakie et al. (1995), where heating and cooling of the forearm was used on a group of air pistol shooters, in order to positively influence tremor size. In a different study, Kruse et al. (1986) examined the effect of β-blockade on hand tremor in pistol shooters and attributed the positive effect to metoprolol. Further, Pellegrini et al. (2004) investigated tremor in shooters t using a laser pointer or an air pistol (Pellegrino and Schena, 2005). Also, Tang et al. (2008) investigated tremor in pistol shooting athletes.

Of relevance, with an applicable transfer to Clay shooting, could have the investigation by Lakie (2010), on the potential influence of temperature and exercises on physiological tremor in Olympic biathletes. Also, the study by Brown et al. (2013), examining the effect of physical exertion on the shooting performance of police officers, could have a pertinent transfer to shotgun disciplines. The authors conclude that fatiguing exercises do not have a perceptible negative effect on the automatic shooting reactions. Other studies investigated the cardiac cycle during rifle shooting in relation to the timing of the trigger pull (Helin et al., 1987; Konttinen et al., 2003; Mets et al., 2007). In a different study, Konttinen et al. (1995) examined the relation between qualitative and quantitative aspects of shooting performance to brain slow potentials. Further, a considerable amount of literature has been published on the occipital electroencephalogram (EEG) alpha-power reactivity during shooting during shooting to calculate brain activity in archery, rifle and pistol shooting (Bird, 1987; Hatfield and Landers, 1987; Hatfield et al., 1984; Haufler et al., 2000; Janelle et al., 2000; Landers et al., 1994; Loze et al., 2001). In another study, Fenici et al. (1999) examined the cardiovascular adaptation during Action Pistol Shooting and reported elevated heart rate and blood pressure, which can be linked to poor shooting performance. Also, based on the study of Mohamed et al. (2014), the ability to control the breathing process can help increase the overall shooting performance of skilled and unskilled archers.

CONCLUSION

Despite the fact that there are some recommendations available regarding the importance of selected physical fitness parameters in the Olympic shooting disciplines of skeet and trap, there is limited research done in this domain. A careful study of the literature reveals that the majority of research has focused on stationary shooting disciplines.

As a summary position of this investigation, postural stability and longer QE duration appear to be critical to successful performance in the Olympic clay target shooting disciplines. Of relevance, and despite the increasing literature surrounding the importance of certain parameters in shooting sport, there is a dearth of knowledge regarding the direct or indirect impact of selected parameters, such as head and jaw position, affecting postural stability (Baldini et al., 2013; Gangloff et al., 2000; Sforza et al., 2006). Also, the importance of the of VO^2 max level for the reduction of anxiety and stress levels, which has a direct positive relationship to QE duration, should be considered in future studies. In addition, the role of strength in Clay shooting has not been investigated as yet. No empirical evidence exists to suggest the importance of grip strength, the strength of the posterior muscle chain, shoulder girdle or trunk, and its influence on postural stability, body sway and the movement of the gun. A clearer understanding of the role of this essential physical parameter is needed in order to identify its importance for the specific motoric action during Clay shooting. Further research in this field would be of great help in improving the performance of the clay target shooting disciplines.

What does this article add?

This article underscores the growing need for better understanding of the role played by certain physical fitness parameters in Olympic clay target shooting. As presented, the majority of research was conducted in other shooting disciplines and this research gap should provide the motivation for a further investigation into the skeet and trap shooting disciplines. Further research would develop and expand the knowledge base within the sport. It would follow that identification, and formative assessment of those parameters should reveal findings that can be applied in practice and utilised with confidence in the training program of clay target shooting athletes.

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