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## **Validity and reliability of the TargetScan ISSF Pistol & Rifle application for measuring shooting performance**

### **Short title: Shooting performance measuring application**

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### **Abstract**

Several technologies, with varying economic costs, are used to measure the performance of Olympic sport shooters, including electronic targets, laser systems, and mobile phone applications. Nevertheless, the International Shooting Sport Federation (ISSF) does not currently accept any mobile applications as valid measurement systems. The objective of the study was to check the validity and reliability of the TargetScan ISSF Pistol & Rifle application, an automatic mobile application for measuring the performance of shooters via image analysis. A total of 1,440 shots were fired by 24 shooters (720 shots each for the air rifle and air pistol events) and the target sheets were analysed with the application installed on an iPhone X. The official competition results and the measurements from the application

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were then compared. The results showed an almost perfect reliability for air pistol shots ( $ICC = 0.999$ ) and no significant differences between the official average scores and those measured by the application. The reliability was also high for air rifle shots ( $ICC = 0.998$ ) but the average scores registered by the application were statistically lower than the official results. We concluded that TargetScan ISSF Pistol & Rifle is a low-cost, valid, and reliable application for measuring amateur and semi-professional shooting performance which may be useful to shooters, coaches, clubs, and federations worldwide.

**Keywords:** smartphone, Olympic shooting, shot performance, scoring system, iPhone

## Introduction

Mobile applications are becoming useful tools in a wide variety of aspects of our lives, and as a result, hundreds of thousands of them are now available and have been downloaded millions of times <sup>1</sup>. Many different types of applications are available in the field of sports and so this highly innovate area of knowledge is becoming increasingly relevant, both at the popular and scientific levels. Two key concepts determine the technical quality of mobile applications and their use: their validity and reliability. Validity is the ability to truly capture the intended measurements, while reliability is the ability to measure with precision and accuracy <sup>2</sup>.

In Olympic sport shooting, the International Shooting Sport Federation (ISSF) establishes both the rules and regulations and the valid systems for determining the results and scores in international-level competitions <sup>3</sup>. Olympic shooting is a sport that requires maximum precision and accuracy to achieve high-level performance. Thus, angular errors greater than  $0.016^\circ$  in the rifle event <sup>4</sup> or  $0.066^\circ$  for pistol shooting <sup>5</sup> can result in scores below the perfect 10 points. Furthermore, the performance level of elite shooters is extremely elevated and equalised between men and women nowadays <sup>6</sup>. Therefore, target-hit scoring must be measured with maximum reliability.

Several devices and mechanisms are currently used for measuring Olympic shooting scores, including electronic targets, optoelectronic and laser systems, target-reading machines, and mobile applications. The ISSF certifies valid measuring devices through a three-phase process: phase I is an accuracy, specification, and build-standard test; phase II tests the device under competition conditions and may lead to its approval for some ISSF competitions or championships; and in phase III, the device is tested for its compatibility under major competition conditions in combination with the ISSF result service and can thereby be approved for all ISSF competitions and championships.

ISSF-validated systems currently include several electronic targets, one target-reading machine, and one laser system, but does not include any applications for measuring the position of the physical impacts of shot pellets <sup>7</sup>. From among the approved measurement systems, the sound or laser position-triangulation technology currently used by electronic targets is preferred because they are more precise than other technologies; however, these systems are also more complex and expensive <sup>8,9</sup>. The ISSF has also certified the ST10L laser system by Shooter Technology <sup>7</sup> and the validity of this latter system correlates well with the findings from previous studies <sup>10</sup>.

Furthermore, several studies have validated both the NOPTEL and SCATT optoelectronic systems for measuring Olympic shooting scores and performance<sup>11,12</sup>. In fact, these measuring methods have related the holding ability, aiming accuracy, cleanness and timing of triggering with the shooting performance<sup>13,14</sup>. However, other studies have indicated certain degree of error with SCATT technology, and some have even called the validity of optoelectronic systems themselves into question, specifically in the shot place coordinates when is compared with the real shot position but not in the group size. Both factors can be modified using the correction factor based on the distance from the aiming point to the centre of the target<sup>15,16</sup> or using Fast Fourier transform analysis to get more information about the magnitude of harmonics frequencies and the shot position<sup>17</sup>. The ISSF also regulates systems for manually scoring shot targets using specific scoring gauges or skid gauges as well as outward scoring gauges for scoring the inner tens for the air pistol and air rifle modalities<sup>3</sup>.

Although the ISSF has not yet recognised the validity of any mobile scoring applications and some studies suggest the importance of collecting data in real competition situations<sup>18</sup>, the use of automatic shooting scoring systems based on target-sheet image recognition has been proposed as a usable system. For example, Lin, Miaou, Lin, Chen<sup>19</sup> validated this technology for pistol shooting without specifying the use of a specific application. Other studies propose using automatic classification systems based on target detection, hole detection, and hole analysis process-phases, and these studies have produced similar results to human scoring<sup>20</sup> and other artificial measurement mechanisms<sup>21</sup>. Moreover, the mathematical algorithms used by detection systems which use cameras and computer software have also been validated<sup>22</sup>.

Despite the availability of these technologies, many countries and sports clubs cannot afford the high economic cost of the different measuring devices available for Olympic shooting, and so they still manually record shooting scores<sup>19</sup>. Thus, the availability of a low-cost mobile application for automatically measuring shooting scores without manual intervention would be very useful. The TargetScan ISSF Pistol & Rifle application is a mobile application for automatically scoring shooting results which has been downloaded thousands of times and has an average user-rating of 4.4/5 on application download sites<sup>23,24</sup>.

To the best of our knowledge, no published scientific studies have validated any mobile applications that score shooting results by scanning Olympic shooting target sheets. Thus, the main objective of this study was to test the validity and reliability of the TargetScan ISSF Pistol & Rifle application for the measurement of Olympic shooting performance. Considering the very high measurement-accuracy required by Olympic shooting, the scientific validation of the accuracy and reliability of this application represents a very innovative challenge. This is especially relevant given that 161 national federations are currently affiliated with the ISSF, making this application potentially very useful to shooters worldwide<sup>25</sup>.

## Materials and methods

### *Sample*

The study sample comprised a total of 1,440 shots (720 in air pistol event and 720 air rifle event shots). To guarantee the results diversity, the shots were fired by 24 shooters (16.7% women) with experience in national or international competitions. Each shooter took a total of 60 shots, in 6 sets of 10 shots. The study was approved by the research ethics committee at the Autonomous University of Madrid.

### *Study design*

First, we registered the official referees' scores obtained during the territorial championship of Madrid. The referees used a Disag RMIV target reading machine, following the instructions for use provided in the user manual<sup>26</sup>. According to the ISSF rules and regulations for championship finals, the range of possible points was 0.0 to 10.9 for the total of 1,440 shots<sup>3</sup>.

Next, we estimated the same measurements with the TargetScan ISSF Pistol & Rifle application, according to the application developers' instructions and according to the following criteria: (a) only official paper targets were used; (b) photographs were taken against a blue background (we used laptop screen); (c) photographs were taken perpendicular to the target using a tripod; (d) the black aiming mark of the target pattern occupied 20÷100% of the image; and (e) the camera distance from the target sheet was 8 cm for pistol shots and 6 cm for rifle shots<sup>27</sup>. The TargetScan ISSF Pistol & Rifle application was installed on an iPhone (model X) with a 12-megapixel rear camera and a wide-angle (f /1.8) aperture was used to measure the target scores using the application. The measurements were carried out by a high-performance shooter from the Spanish national team who used this application daily (see Figure 1).

In order to test both the intra-observer reliability (test-retest) and inter-observer reliability (reliability between two observers) of the measurement accuracy of the application, two external observers also analysed 120 targets (60 target sheets each for the air pistol and air rifle events) using TargetScan ISSF Pistol & Rifle. These targets were measured twice, with a period of ten days between these two measurements.

### *Statistical analyses*

We recorded the following descriptive statistics: minimum and maximum values, results range or amplitude, summation of scores, arithmetic mean, and standard deviation. Paired *t*-tests and intraclass correlation coefficients (ICCs) were used to analyse the data, in addition to scatter plots and Bland–Altman graphs. The analyses were carried out using IBM SPSS Statistics (version 25) and EpiDat software, establishing a 95% confidence level ( $p < 0.050$ ) for the probability of statistical significance in all cases.

## Results

The pistol and rifle results officially registered by the Disag RMIV instrument versus those from the TargetScan ISSF Pistol & Rifle application are shown in Table 1. Almost perfect reliability was achieved between both methods for the pistol event ( $ICC = 0.999$ ,  $p < 0.001$ ) and the means recorded by the application ( $9.095 \pm 1.058$ ) and the Disag RMIV ( $9.093 \pm 1.059$ ) were statistically equal ( $p = 0.336$ ). Moreover, the total points sum for the 720 pistol shots were near identical for both registers (6,548.100 versus 6,547.100). A high level of reliability was also observed between these two methods for the rifle event ( $ICC = 0.998$ ,  $p < 0.001$ ), although the average score registered with the application ( $9.525 \pm 0.997$ ) was lower ( $p < 0.001$ ) than the official registration ( $9.543 \pm 1.003$ ). Thus, the sum of the rifle points registered by TargetScan ISSF Pistol & Rifle (6,857,800) was lower than that from the official Disag RMIV point scoring instrument (6,870.700).

Scatter-plot graphs show that the range of pistol results ( $\approx 8,050$  points; Figure 2A) was wider than that for the rifle event ( $\approx 6,600$  points; Figure 2B). The Bland–Altman graphs show that the discrepancy between the official records and those recorded by the application for the pistol event were distributed randomly and fall above and below the confidence-interval limits (Figure 2C). However, there were more disagreements below the lower confidence interval limit for the rifle event because of the application underscoring some shots compared to the official record (Figure 2D).

The both the intra-observer and inter-observer reliability of the TargetScan ISSF Pistol & Rifle application are shown in Table 2. In both cases, the reliability of the application for the pistol event was almost perfect ( $ICC = 0.999$ ;  $p < 0.001$  in both cases). The reliabilities were also high for the rifle event but were slightly lower than for the pistol event ( $ICC = 0.984$  and  $0.996$  for inter-observer and intra-observer reliability, respectively;  $p < 0.001$  in both cases).

## Discussion

Our data indicate that the TargetScan ISSF Pistol & Rifle application is a valid and reliable way to measure Olympic shooting performance. For pistol shooting, its intra- and inter-observer reliability was near perfect in both cases; the reliability values for rifle were slightly lower than those for pistol but were also high (Table 2). This is a relevant finding because the high levels of precision and reliability required by this sport mean that not all measurement systems can be used in Olympic shooting<sup>4,5</sup> but these data indicate that TargetScan ISSF Pistol & Rifle meets these criteria.

Only a few shot-measuring systems have been validated by the ISSF for measuring Olympic sport shooting performance. These validated systems include electronic targets, target-reading machines, and laser systems<sup>10–12</sup> but exclude mobile phone applications. Here we set out to scientifically test, for the first time, the validity and reliability of the TargetScan ISSF Pistol & Rifle application<sup>7</sup> for measuring sport shooting performance.

In accordance with previous studies that confirmed the validity of position and image recognition-based shot-identification systems<sup>19–21</sup>, the results of this study show high



reliability values for TargetScan ISSF Pistol & Rifle. Indeed, our results are similar to other studies which showed a 99% shot-identification success rate<sup>20</sup> and very low measurement deviation error values of 0.1<sup>20,21</sup>. Thus, the reliability indices we obtained in this study are comparable to other laser measurement systems already validated by the ISSF which have estimated shot-identification success rate values of 94% to 100%, depending on the lighting conditions<sup>21</sup>.

Nevertheless, the scores recorded using the TargetScan ISSF Pistol & Rifle application for the rifle modality were slightly lower than the results registered by the officially-used Disag RMIV device. This could be explained by the following reasons: a) The smaller target size used in rifle, specifically the 10-point size ( $0.5 \text{ mm} \pm 0.1 \text{ mm}$  for rifle and  $11.5 \text{ mm} \pm 0.1 \text{ mm}$  for pistol), which can increase the measurement error in rifle; b) The camera range or angle errors. The perspective errors can decrease the precision of the measurement. The optimal angle of the target plane and an optical axis should be 90 degrees. Furthermore, the focal length of the camera should be enough to detect inner ring lines in order to calibrate the pattern perfectly; c) The megapixel resolution of the camera. The more megapixel resolution the more accurate will be the measurement<sup>3,20,27</sup>. Of note, as also occurs in official championships, the rifle scores we recorded were higher and more centred<sup>28</sup>. For example, the scoring ranges for the rifle event were lower than for pistol modality, with a minimum score of 4.3 points for rifle and 2.8 for the pistol event.

Taken together, these data indicate that the TargetScan ISSF Pistol & Rifle mobile application is scientifically reliable<sup>2</sup> and could be useful to amateurs. However, the average difference between the application score and the official record corresponds to 1.1 points per 60 shots which, for the last shooting world cup held in New Delhi<sup>28</sup>, for men would have been equivalent to a finalist attaining the second-best score versus a competitor not placing in the final at all, or for women, it would be the same as reaching the final or not, and would have made a difference of up to 11 positions in the general women's classification.

Another possible problem lies in establishing national and world records using TargetScan ISSF Pistol & Rifle because, although the measurement error of this application was minimal, this difference could still be decisive. Furthermore, other studies have suggested that performance measurement of high-level rifle shooters requires professional instrumentation<sup>20</sup>. Consequently, the use of the TargetScan ISSF Pistol & Rifle application for professional-level rifle competitions may not be appropriate.

To the best of our knowledge, this the first scientific study to validate a mobile application for measuring shooting performance. However, the main limitation of this study was that we were unable to find any details about registration with the TargetScan ISSF Pistol & Rifle application, especially in terms of three important aspects: (a) the use of different types of targets and the required focal lengths from the target to the mobile phone camera; (b) the minimum camera technical specifications required; and (c) the luminosity required to take accurate measurements using this application. Therefore, future studies will be necessary to test the protocols both for the use of TargetScan ISSF Pistol & Rifle itself and to define the type of camera needed to achieve maximum reliability using this application, especially for the rifle modality. Likewise, other comparative studies should be carried out to compare TargetScan ISSF Pistol & Rifle with other applications on the market.

## Perspectives

The present study has a practical meaning rather than solving a scientific problem. TargetScan ISSF Pistol & Rifle is currently a very popular and commonly used sports shooting application with thousands of downloads<sup>23,24</sup> and the data from this study confirm that it is a valid and reliable tool, especially for amateur and semi-professional use. This application measures shooting performance with an almost perfect reliability for pistol shooting and very high reliability values for the rifle modality. Thus, we consider the TargetScan ISSF Pistol & Rifle application to be a valid, reliable, and low economic cost tool appropriate for use by shooters, coaches, clubs, and federations worldwide.

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- Accepted Article
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**Table 1**

TABLE 1. Results of scores with the ISSF TargetScan application versus the official Disag RMIV register for the pistol and rifle events.

	Pistol		Rifle	
	ISSF TargetScan application	Official Disag RMIV register	ISSF TargetScan application	Official Disag RMIV register
Minimum value	2.800	2.900	4.300	4.300
Maximum value	10.900	10.900	10.900	10.900
Range or amplitude	8.100	8.000	6.600	6.600
Summation	6,548.100	6,547.100	6,857.800	6,870.700
Arithmetic mean	9.095	9.093	9.525	9.543
Standard deviation	1.058	1.059	0.997	1.003
Paired <i>t</i> -test	<i>t</i> = 0.962, <i>df</i> = 719, <i>p</i> = 0.336		<i>t</i> = -7.230, <i>df</i> = 719, <i>p</i> < 0.001	
Reliability	ICC = 0.999; <i>p</i> < 0.001		ICC = 0.998; <i>p</i> < 0.001	
Annotations: <i>t</i> = value of paired <i>t</i> -test; ICC = intraclass correlation coefficient; <i>df</i> = degrees of freedom; <i>p</i> = probability of statistical significance.				

**Table 2**

TABLE 2. Intra-observer (test-retest) and inter-observer reliability values measured by the TargetScan ISSF Pistol & Rifle application.

Event	<i>N</i>	Reliability			
		Intra-observer		Inter-observer	
		Observer 1	Observer 2	Measurement 1	Measurement 2
Pistol	60	0.999*	0.999*	0.999*	0.999*
Rifle	60	0.995*	0.996*	0.995*	0.984*
Annotations: <i>N</i> = number of targets, * = value of the intraclass correlation coefficient, applying a probability of statistical significance of < 0.001.					

**Figure 1**



Figure 1. Measurement of a pistol target using the TargetScan ISSF Pistol & Rifle application.

**Figure 2**

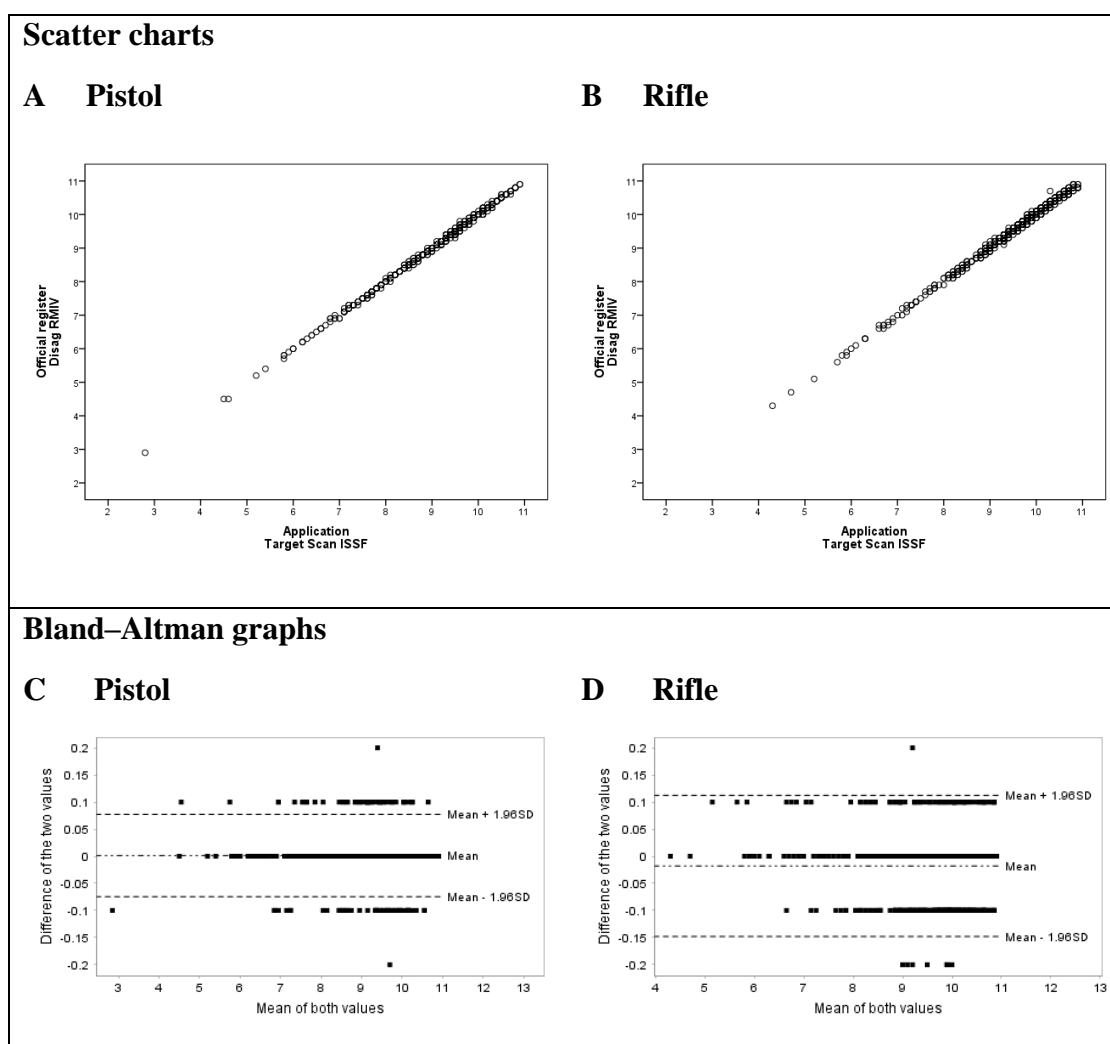


Figure 2. Scatter charts measuring the correlation between official Disag RMIV register and the ISSF TargetScan application for (A) the pistol event and (B) the rifle modality and Bland-Altman graphs comparing the difference between the mean values measured by the official Disag RMIV register and the ISSF TargetScan application for (C) pistol shooting and (D) the rifle event.