Mon, D.; Zakynthinaki, M.S.; Cordente, C.A.; Barriopedro, M.I. y Sampedro, J. (2016). Prevalidación de un test de equilibrio en tiro olímpico sin armas / Prevalidation of Body Sway Shooting Test Without the Use of Weapons. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 16 (64) pp. 775-787. Http://cdeporte.rediris.es/revista/revista64/artvalidacion763.htm
DOI: http://dx.doi.org/10.15366/rimcafd2016.64.010

ORIGINAL

PREVALIDATION OF BODY SWAY SHOOTING TEST WITHOUT THE USE OF WEAPONS

PREVALIDACIÓN DE UN TEST DE EQUILIBRIO EN TIRO OLÍMPICO SIN ARMAS

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AGRADECIMIENTOS: Consejo Superior de Deportes (Spain), Real Federación Española de Tiro Olímpico (Spain), Facultad de Ciencias de la Actividad Física y del Deporte-INEF (Spain).

Código UNESCO / UNESCO code: 2411.01 Fisiología del equilibrio/ Balance Physiology
Clasificación Consejo de Europa / Council of Europe classification: 17 Otras: (rendimiento deportivo)/ Others: sports performance

Recibido 10 de febrero de 2014 **Received** February 10, 2014
Aceptado 16 de septiembre de 2015 **Accepted** September 16, 2015

ABSTRACT

The main objective of the present work is the pre-validation of a test able to provide reliable body sway measurements in Olympic shooting, without the use of a pistol. For this reason the results of the analysis of the body sway data of two static bipodal body sway tests have been compared: during the first a dumbbell was used to simulate shooting, while for the second test a pistol was used. A strong correlation between the two tests regarding all variables was found. A statistically significant inverse linear correlation was also found between body weight and the movements of the COP (centre of pressure). No statistically significant relations were found between the movements of the COP and performance. The study concludes that dumbbell tests could be perfectly reliable for measuring specific body sway on Olympic shooting. Future studies on the validation of the same test with larger sample size are recommended.

KEY WORDS: Olympic shooting, pistol, body sway, centre of pressure, dumbbell.

RESUMEN

El principal objetivo de este estudio es realizar un estudio previo a la validación de un test de medición del equilibrio en tiro olímpico sin el uso de la pistola. Para ello, se han comparado los resultados del análisis del movimiento del centro de presiones (CP) de dos pruebas de equilibrio estático: en la primera prueba se usó una mancuerna para simular la acción de disparo, mientras que en la segunda se usó la pistola. Se encontró una fuerte correlación entre los dos test en todas las variables del CP y una correlación lineal inversa entre el peso corporal y los movimientos del CP. No se encontró relación alguna entre los movimientos del CP y el rendimiento deportivo. El estudio concluye que el test con mancuerna puede ser válido para la medición del equilibrio específico en tiro olímpico y se recomienda profundizar en el estudio con una muestra de mayor tamaño.

PALABRAS CLAVE: Tiro olímpico, pistola, equilibrio, centro de presiones, mancuerna.

1. INTRODUCTION

Olympic shooting is a "precision and accuracy sport", as the target dimension is very small (in air pistol, for example, the area of 10 points has a diameter of 11,5mm+-0,1mm) in comparison to the shooting distance of 10m. It is a sport that demands exceptional concentration and a strong mental approach. The actual world record is 594 (with the maximum being 600 points), which is equivalent to an average score of 9.9 per shot or 99% success (RFEDETO, 2012b). This implies that the slightest uncontrolled movement can lead to failure.

Many are the factors that affect performance in Olympic shooting, including the shooter's overall fitness (Krasilshchikov, Zuraidee, & Singh, 2007), their muscular ability to resist fatigue (Niinimaa & McAvoy, 1983), the coordination between shooting time and trigger pressing (Viitasalo et al., 1999; Zatsiorsky & Aktov, 1990) as well as experience and training (Goonetilleke, Hoffmann, & Lau, 2009).

Even though no specific body morphology seems to exist in Olympic shooting, the Olympic shooters seem to be shorter and heavier than other athletes (Belinchon, 2010). Body weight seems to affect the stability of the body, as COP (centre of pressure) movements are larger in heavier subjects (Hue et al., 2007). Similarly, Ku, Abu Osman, Yusof, and Wan Abas (2012) found an inverse correlation between the BMI (Body mass index) and body sway in adolescents. Other studies in adolescents, however, found no correlation between COP movements and body weight (King, Challis, Bartok, Costigan, & Newell, 2011). The specialized studies that can be found in the literature present no consensus on this subject.

A consensus seems to exist, however, on the importance of the ability to stabilize the pistol (Mononen, Konttinen, Viitasalo, & Era, 2007; Pellegrini & Schena, 2005; Reinkemeier, Bühlmann, & Konietzny, 2006). This stabilizing ability is closely related to body movements: (Pellegrini & Schena, 2005) showed that the body movements along the X axis (anterior-posterior) are related to lateral movements of the pistol (along the Y axis) and that the vertical movements of the pistol (frontal plane) are related to arm movements caused by variations in the position of the shoulder. Other studies (Tang, Zhang, Huang, Young, & Hwang, 2008) observed that the stability of the arm-pistol complex is closely related with performance, as higher level shooters were shown to have a better ability to stabilize the pistol.

The main objective of the shooters is to achieve as much stable pistol movements as possible. As a matter of fact, the time within the area of 9 has been characterized as the most important variable that determines performance (Hawkins, 2011). Perfect stabilization against gravity is, however, complicated and subjected to a number of factors that determine the level of muscular tremor, such as muscle temperature, caffeine intake, blood adrenaline levels, heart and respiration rates, or the age of the shooter (Lakie, 2010).

There seems to be a consensus that the stabilization of the pistol, and consequently the level of performance, is affected by COP movements (Ball, Best, & Wrigley, 2003; Mason, Cowan, & Gonczol, 1990; Viitasalo, Era, Mononen, Norvapalo, & Rintakoski, 1998). Significant relations have been reported between performance and COP movements in experienced, but also in novice shooters (Era, Konttinen, Mehto, Saarela, & Lyytinen, 1996; Mononen et al., 2007). The degree of influence of this variable remains, however, still under scientific discussion.

All studies that can be found in the literature measure COP movements when shooting is performed by use of a real pistol. In order, however, to have an appropriate early talent detection tool, that would be also able to be carried out at any place, it would be interesting to develop and validate a specific test that would not require the use of a pistol and would be reliable for the determination of a shooter's stability as well as their COP movements. The objectives of the present work are, therefore, to carry out a study that would disclose the possibility of validating a test capable measure the COP movements in Olympic shooting without use of a pistol and to confirm the relation between COP movements, performance and the shooters' body morphology.

2. MATERIAL AND METODOS

2.1. PARTICIPANTS

The study is based on data of 11 shooters who belonged to the Spanish talent selection group, 8 boys and 3 girls.

It should be noted here that, although a sample of such small size impedes the validation of the test under study, due to its inadequate statistical power, we considered interesting not to augment it. As will be described in detail below, the study is based on exceptional data, collected under competition conditions and by high level shooters, a fact that definitely enhances the soundness of the present study.

2.2. MATERIAL

A portable force platform (Kistler 9286AA) was used to record the movements of the COP on the X (anterior-posterior) and the Y (medio-lateral) axes at a frequency of 100 Hz.

Performance was measured by use of official paper targets, according to the International Shooting Sport Federation (ISSF) Rules and Regulations (RFEDETO, 2012b).

2.3. METHOD

The protocol consisted of two static bipodal body sway tests:

For the first test, a 1.5 kg dumbbell was used, simulating shooting action and position. The dumbbell’s weight corresponds to the maximum official pistol weight, as established by the rules and regulations (RFEDETO, 2012b). The test was performed following the criteria of the study of (Gulbinskienė & Skarbalius, 2009), ensuring the similarity of the technique with the actual shooting gesture.

In order to respect the individual needs and characteristics of each shooter, the feet position during shooting was free, exactly as at competition. To visually complete the simulation of a shot, the targets used were official paper targets.

The duration of each repetition of this test was 30seconds. The start of each recording was the moment the athletes were ready to shoot. Aiming to respect the actual competition rhythms, as set by the rules and regulations (RFEDETO, 2009), a resting period of was allowed between each repetition, being a maximum of 1’45” for females and 1’52” for females (a minimum resting period was allowed, however, depending on the individual athlete, so as to respect the individual needs and characteristics).

During the second test, the participants used their pistol to shoot. The pistol characteristics used in all cases met the specifications of Article 8.16.0 of the specific regulation of air pistol shooting (RFEDETO, 2012a).

In order to determine performance, the second test consisted of two sub-tests: 3 training shots were performed (with COP measurements on the force platform) followed by 40 shots under competition conditions (RFEDETO, 2012a, 2012b).

Both tests were repeated three times for each subject as suggested by (Pinsault & Vuillerme, 2009) and took place at a training stand, to assure similar competition conditions regarding the luminosity, the temperature, the floor type, or the distance to the target.

The local ethics committee provided an approval for the present study and an informed consent was signed by all the participants before data collection. We confirm that our research meets the highest ethical standards for authors and co-authors. The study was performed following the guidelines of the Declaration of Helsinki, last modified in 2008.

The authors certify that the present research was carried out in the absence of any financial, personal or other relationships with other people or organizations that could inappropriately influence, or be perceived to influence, the presented work and lead to a potential conflict of interest.

2.4. VARIABLES AND STATISTICAL ANALYSIS

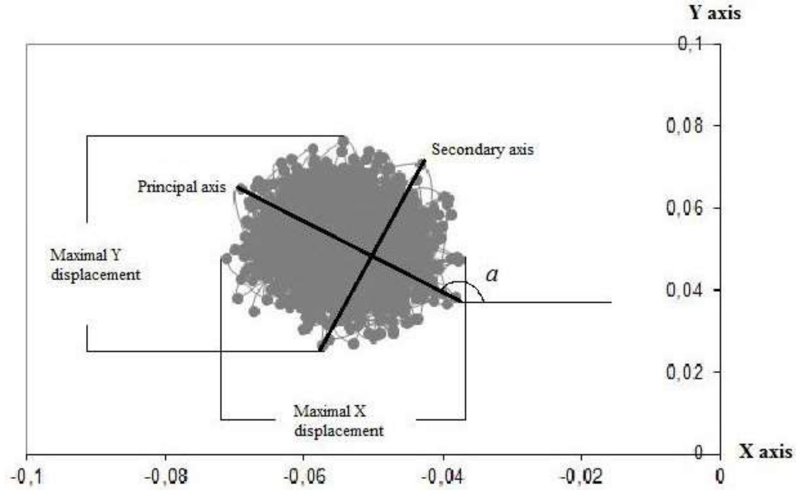
The variables analysed regarding the participants profile were, weight, height, experience, training hours per week and performance. The characteristics of the group of the participants are shown in table 1.

Table 1. Age (years), height (cm), weight (kg), weekly training hours and experience (years). Mean values ±SD.

	Mean ± SD
Age	15,45±1,86
Height	171±0,1
Weight	71,02±19,74
Training	6,59±2,44
Experience	2,11±1,7

Various variables related to COP movements were also analysed. These variables, which can be seen in Graph 1, are the maximal COP displacements on the X and Y axes, the length of principal and secondary axis of the ellipse that best fits the COP data in respect to the X and Y axis coordinate system, as well as the total area of COP displacements and average and maximum COP velocities on the force platform plane and along the X and Y axes.

Graph 1: Maximal COP displacement along the X and Y axes. Length of principal and secondary axis of the ellipse that best fits the COP data in respect to the X and Y axis coordinate system.



The Kolmogorov-Smirnov test was used to determine the goodness of fit to the normal distribution of the variables. The Mann-Whitney U test was used to compare the differences between sexes. To examine the relations between performance/weight and COP movements of the participants, Pearson product moment correlations were used. In order to analyze the concurrent validity of the variables for both tests, the intraclass correlation coefficient (ICC) was calculated. The level of significance was set at 0.05.

The statistical analysis of the variables was performed using SPSS PASW Statistics 17. The calculation of the displacements, speeds, areas and angles was done by use of the mathematical package Matlab R2009a.

3. RESULTS

Among the group of participants, the boys were found to be significantly taller than the girls ($Z=2.15$; $p<0.05$), having an average height of 174,5±0,9cm (in comparison to the average height of the girls, which was 160,07±0.57). Regarding the other variables shown in table 1, no significant differences were found between males and females.

Table 2 presents the values of the variables referring to the movement of the COP of the participants, during both tests.

Table 2. Mean ± standard deviations of the variables referring to the movement of the COP of the participants. Units of COP measures are as follows: COP displacements: $m*10^{-3}$; area: $m*10^{-6}$; COP velocities: $m/sec*10^{-3}$

	Pistol test			Dumbbell test		
	Mean	±	SD	Mean	±	SD
Max. displ. X	37,02	±	7,77	33,93	±	5,47
Max. displ. Y	47,97	±	12,23	46,1	±	13,14
Principal axis	38,9	±	8,27	35,57	±	6,09
Secondary axis	48,58	±	12,05	47,63	±	13,83
Total area	1.549,1	±	682,5	1.378,52	±	596,14
Aver. velocity X	246,95	±	63,58	213,73	±	53,8
Max. velocity X	1.109,04	±	289,96	1.003,44	±	259,02
Aver. velocity Y	386,17	±	112,49	345,17	±	99,09
Max. velocity Y	1.716,38	±	453,8	1.603,49	±	481,26
Aver. COP velocity	502,57	±	140,19	444,83	±	122,26
Max. COP Velocity	1.754,03	±	455,89	1.626,12	±	490,73

No significant correlations were found between performance and COP movements, $p>0.05$. Significant correlations were found, however, between the weight of the participants and COP movements, oscillating between $r=-0.65$ and $r=-0.97$, as can be seen in Table 3.

No significant correlation was found between the weight of the participants and performance, neither during the 3 test shots, $r^2=0.14$; $p>0.05$, nor during competition, $r^2=0.01$; $p>0.05$.

Table 3. Pearson correlations between the variables that refer to COP movements, performance (3 and 40 shots) and weight of the participants.

	Pistol test			Dumbbell test		
	Performance 3 shots (test)	Performance 40 shots (competition)	Weight	Performance 3 shots (test)	Performance 40 shots (competition)	Weight
Max. Displ. X	-0,38	-0,21	-0,87**	-0,22	0,02	-0,65*
Max. Displ. Y	-0,37	-0,04	-0,94***	-0,44	-0,2	-0,96***
Principal axis	-0,42	-0,22	-0,9***	-0,13	-0,02	-0,74**
Secondary axis	-0,36	-0,01	-0,94***	-0,36	-0,12	-0,95***
Total área	-0,41	-0,15	-0,93***	-0,31	-0,17	-0,92***
Aver. velocity X	-0,41	-0,23	-0,96***	-0,48	-0,23	-0,89***
Max. Velocity X	-0,29	-0,27	-0,93***	-0,44	-0,14	-0,84**
Aver. velocity Y	-0,37	-0,15	-0,97***	-0,42	-0,22	-0,93***
Max. Velocity Y	-0,36	-0,07	-0,95***	-0,44	-0,09	-0,95***
Aver. COP Velocity	-0,38	-0,17	-0,97***	-0,44	-0,22	-0,92***
Max. COP Velocity	-0,39	-0,14	-0,95***	-0,45	-0,1	-0,95***

*** Significance level 0,001 (unilateral).
** Significance level 0,01 (unilateral).
* Significance level 0,05 (unilateral).

The analysis of the intraclass correlation coefficient for the variables that refer to COP movements, for the data of both tests (pistol and dumbbell tests) revealed significant results (greater or equal to 0.90) for all variables (table 4).

Table 4. Intraclass correlation coefficient for the variables that refer to the movement of the COP, for the data of both tests.

Max. Displ. X	ICC
Max. Displ. Y	0,9*
Principal axis	0,98**
Secondary axis	0,91*
Total area	0,98**
Aver. velocity X	0,98**
Max. Velocity X	0,96**

Aver. velocity Y	0,9*
Max. Velocity Y	0,98**
Aver. COP Velocity	0,99**
Max. COP Velocity	0,97**
Max. Displ. X	0,99**

* Significance level p<0.01;
** Significance level p<0.001

4. DISCUSSION

Static balance seems to play a fundamental role in the efficient stabilization of the pistol in Olympic shooting (Reinkemeier et al., 2006). Measurements of static balance are reported in the literature in terms of body sway and COP movements (Pellegrini & Schena, 2005; Tang et al., 2008) and, as the use of a pistol is essential in air pistol Olympic shooting, the majority of the studies use a pistol for the data collection. This need of a pistol can, however, be a drawback, especially during talent selection tests that could take place in schools or sport centres where the use of weapons is prohibited.

There is, therefore, the need, both from the athletic and the social point of view, for the development of a valid and reliable test, able to evaluate the specific body sway of young athletes without the use of a pistol. The use of standardized and financially affordable materials, such as dumbbells to replace the pistols, and Wii balance boards (45 cm x 26.5 cm) to measure body sway, instead of force platforms (as proposed by Clark et al., 2010) like the one used in the present study (Kistler 9286AA) could dramatically decrease the cost of materials used and facilitate the carrying out of the tests at any place.

Regarding the validity of a test that can be performed without the use of a pistol, the results of the present study showed an intraclass correlation coefficient that varied between 0.9 and 0.99. We can therefore say that the dumbbell test is possibly valid, although future studies with larger sample size are necessary in order for our results to be confirmed.

Further analysis of the data of the present study showed no statistically significant relation between the movements of the COP and performance, in contrast to existing studies (Mason et al. 1990; Viitasalo et al. 1998 Mononen et al. 2007). A tendency of an inverse linear corelation was found, however, regarding all the variables used to characterize the movements of the COP, showing that shooters with less body sway tend to perform better. This result could be due to the limited number of participants of the present study and the subsequent limited statistical power of the data used for the analysis.

A statistically significant inverse linear correlation was found between body weight and COP movements. We therefore conclude that the weight of a shooter is a strong predictor of body sway, in accordance with the study of (Hue et al., 2007). It should be mentioned here that the study of (Hue et al., 2007) reports a positive correlation between body weight and body sway, in contrast to the negative correlation that revealed the analysis of the present study. The difference can be explained by taking into account that Olympic shooters are generally heavier than athletes of other sports, as reported by (Belinchon, 2010). It seems logical that an increase in body weight could be technically beneficent to an Olympic shooter, since for heavier shooters the magnitude of the angular momentum produced by the pistol around the shoulder will be small in comparison to that of the angular momentum of the shooter's body; therefore heavier shooters should be expected to have a better ability to stabilize the pistol and therefore less COP movements. Future studies are necessary to confirm this hypothesis.

Finally, the present study's main limitation, the small sample size, can be justified when one takes into account the participants' high level and the data recording protocol, i.e. actual competition conditions. Despite the fact that with such small sample size no definite conclusions regarding the validity of the test can be derived, we believe that the present study which involved high level participants and a exceptional data recording protocol provides valuable data that can serve as reference for the validation of the dumbbell test in future studies.

5. CONCLUSIONS

The present study showed that:

1. There is a strong correlation between body weight and body sway in young air pistol shooters.

2. Dumbbell tests seem to be perfectly reliable for measuring body sway in young air pistol shooters.

3. Further studies with larger sample size are necessary in order to validate the proposed test.

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