Original Paper

Biomedical Human Kinetics, 6, 56–62, 2014
DOI: 10.2478/bhk-2014-0010

Body sway and performance at competition in male pistol and rifle Olympic shooters

Daniel Mon[1], Maria Zakynthinaki[2], Carlos Cordente[1], Maria Barriopedro[1], Javier Sampedro[1]

[1] Facultad de Ciencias de la Actividad Física y del Deporte – INEF, Universidad Politécnica de Madrid, c/ Martin Fierro 7, 28040 Madrid, Spain; [2] Applied Mathematics and Computers Laboratory, Technical University of Crete, 73134 Chania, Greece

Summary

Study aim: We examine the body sway differences between a) pistol and rifle and b) elite and national level senior male Olympic shooters, as well as the possible relation between body sway and performance at competition in Olympic shooting.
Material and methods: Two body sway tests (feet together and feet apart) were performed by 28 Spanish male senior Olympic shooters just before competition. Performance was measured as the actual score at competition. Total center of mass (COM) areas and average/maximum COM velocities were calculated from force platform data. ANCOVA tests were implemented with age as a covariable. The non-parametric test U of Mann Whitney was used to study the differences between national and elite shooters. Pearson correlations were used to examine the relation between performance and total COM area.
Results: At the feet apart position, rifle and elite shooters were found to have statistically less body sway than pistol and national level shooters respectively (total COM areas: $F_{1,25} = 6.7$; $p < 0.05$, and $Z = 2.36$; $p < 0.01$). No statistically significant differences were found regarding the feet together position, regardless the level or discipline (total COM areas: $F_{1,25} = 1.49$; $p > 0.05$; $1 - \beta = 0.22$, average COM velocities: $F_{1,25} = 0.58$; $p > 0.05$; $1 - \beta = 0.11$, maximum COM velocities: $F_{1,25} = 0.03$; $p > 0.05$; $1 - \beta = 0.05$). No significant relation was found between body sway and performance at competition (feet together: $r = 0.13$, feet apart: $r = 0.14$, $p > 0.05$). Age and body sway were not found to be significantly correlated ($F_{1,25} = 0.23$; $p > 0.05$; $1 - \beta = 0.08$).
Conclusions: Easy to carry out, non-specific body sway tests can be used for the selection of novice shooters.

Keywords: Olympic shooting – Body sway – Performance – Center of mass

Introduction

Olympic shooting requires maximum precision and control [8, 25] as any involuntary or uncontrolled movement can easily cause failure. According to the experience of the coaches, one of the main factors that determine performance in Olympic shooting is body sway (see [21] for pistol and [28] for rifle shooting respectively). Higher level shooters are assumed to have less body sway [1, 11, 13], even though the motor strategy is thought to be similar in all levels [9]. It seems logical to assume that athletes with less body sway have an inherent advantage to become better shooters [2]. If this hypothesis was to be confirmed, then body sway measurements could be included as diagnostic tests of performance in Olympic shooting.

A consensus seems to exist in the literature regarding the influence of body sway in the movements of the gun barrel. A direct correlation has been found using in rifle specific tests [16] between body sway and movements of the gun barrel, while other authors [3] found the same direct correlation in pistol specific tests in 80% of the cases. The movement in the COP (Center of Pressure) of a pistol shooter determines the movement of the gun-body system in the horizontal axis [19]. Other rifle specific tests revealed a direct association between COP movements on the anterio-posterior axis and vertical movements of the rifle barrel [18].

No consensus exists, however, regarding the influence of body sway on performance. It has been reported that body sway in running target shooting can predict performance with an accuracy of 75% [24]. Other studies showed that the body sway results to a variability in performance of 53% amongst elite pistol shooters [15] and report the association of increased body sway with increases in the movement of the gun barrel in rifle shooting [4]. Other

Author's address Maria S. Zakynthinaki, Applied Mathematics and Computers Laboratory, Technical University of Crete, 73134 Chania, Greece marzak@science.tuc.gr

researchers obtained a correlation of 26% between balance and shooting accuracy and performance in novice rifle shooters [16]. In other studies, however, a correlation was found between performance and body sway in only the 1/5 of the pistol shooters [3] or only in novice rifle shooters [8].

It should be noted that the existing studies on Olympic shooting are based on data recorded under laboratory during shooting simulations [3,4,17,28] or during training [14, 23]. The most reliable measurement of performance is, however, the score obtained at competition. Moreover, the reliability of opto-electronic training systems [17] is under question [28]. As long as performance is measured outside competition conditions, its exact relation with body sway is therefore bound to be unknown.

When examining body sway or performance in Olympic shooting, one should also take into account that there exist technical differences between the two disciplines (different placement of the body`s segments, different position and weights of the gun), different balance control requirements (a score of 10 points refers to a target of 11.5 mm + – 0.1mm diameter in pistol shooting in contrast to a target of 0.5 mm + – 0.1mm diameter in rifle shooting [22]) and the effect of supportive clothing. Regarding differences in performance, a limited amount of studies can be found in the literature: it has been reported [1] that the supporting jackets, trousers and shoes used in rifle shooting can increase performance up to 20%. Regarding body sway differences, no studies exist that compare between the disciplines.

The present study is based on body sway and performance data that were measured under competition conditions. The objectives were to a) compare the body sway between rifle and pistol Olympic shooters as well as between elite and national level Olympic shooters and b) examine the correlation between body sway and performance at competition in Olympic shooting.

Material and methods

Participants

The participants of this study competed at the Spanish national pistol and air rifle championships that took place in Madrid, Spain, in December 2010. According to the regulations of the Spanish Federation of Olympic shooting (2010) eligibility to compete required a minimum score of 510 points in air pistol and 530 points in air rifle in other previous national competitions (maximum score = 600 points [22]). The participation to the study was voluntary and open to all competing shooters of the senior male category during the limited official training time before competition (4 testing days in total). The participants included shooters who had a minimum shooting experience of 10 years and had not suffered any injuries during one year previous to the competition.

A total of 28 Spanish male senior shooters aged 41.83 ± 9.22 years old participated in this study. Of the 28 participants, 22 were pistol shooters (78.57%), with a mean age of 43.74 ± 7.51 years old, 2 of whom belonged to the elite Spanish team, and 6 were rifle shooters (21.43%), with a mean age of 34.50 ± 12.11 years old, 2 of whom were elite shooters of the Spanish team. A shooter was considered to be of elite level if they had participated in the finals of World championships, World cups, European championships, or had participated in any Olympic Games. The senior category is referred to the age of the shooters and included shooters between 21 and 54 years old.

Measures and Procedures

The protocol consisted of two non-specific and simple to carry out body sway tests that were performed with eyes open in a static bipodal position, barefoot and with hands on hips. The tests were performed just before competition (either the day of the competition just before competing, or one day before competition, during training time). To minimize the possible effects of stress differences due to the difference in time between testing and competition, a homogeneous distribution of the number shooters of both disciplines that were tested was assured: 15 shooters (11 pistol and 4 rifle) were tested on the day of competition, just before competing and 13 shooters (11 pistol and 2 rifle) were tested one day before competing. Regarding the level, 14 national level shooters and only 1 elite shooter were tested on the day of competition.

A portable force platform (Kistler 9286AA) and its corresponding software and hardware were placed at one of the official competition stands to record the time series data of the three components (antero-posterior, medio-lateral and vertical) of the ground reaction force exerted by the shooters with a recording frequency of 100 Hz. During the first test the shooters were asked to remain in quiet upright position on the force platform during 20 seconds with feet together. During the second test (which also lasted 20 seconds) the participants were asked to place their feet apart in the position that felt more stable and comfortable. In order to minimize the body sway during the tests, the participants were advised to stand “as still as possible” [20, 31] and to remain in apnea [6, 21]. A rest of 1 to 3 minutes was allowed between both tests.

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.

Statistical analysis

The present study is based on the kinematic data of the COM (Center of Mass) of the shooters. According to the scientific literature, it is misleading to refer to the movements of COP as "sway", a term which should actually refer to the COM [26]. In addition, while the COP is the neuromuscular response to the body's COM, both signals are virtually in phase but the COP oscillates around the COM in order to decelerate and reverse its direction [26].

The COM time series were obtained from the recorded time series data, by use of basic Newtonian mechanics [7, 30]. The (relative) change of the movement of the COM on the horizontal plane (the plane of the force platform) was numerically determined by calculation of a double time integral of the total horizontal normalized ground reaction force [7]. For the numerical integration Simpson's rule [5] was implemented by use of the mathematical package Matlab R2009a.

The total area of the body sway, in terms of movements of the COM on the horizontal plane, was calculated using Matlab R2009a [27]. Maximum and average values of the COM velocity have also been calculated. The time series of the velocity of the COM were obtained by the time series of the recorded forces by use of Newton's central difference differentiation algorithm [5] for the calculation of the derivative in respect to time.

The shooters' official score obtained at competition was measured by use of official paper targets [22]. The maximum points at competition were normalized before analysis.

The statistical analysis of the variables was performed using SPSS Statistics 17. Since a statistically significant difference exists regarding age between pistol and rifle shooters, ANCOVA tests were implemented with age as a covariable. The non-parametric test U of Mann Whitney was used to study the differences between national shooters and elite shooters. The Kolmogorov-Smirnov was used to determine goodness of fit to the normal distribution of the variables. The level of significance was set at 0.05 and power ($1 - \beta$) was calculated for not significant results. To examine the relation between performance and total COM area of the shooters, Pearson correlations were used.

Results

The values of the total COM areas calculated from the data recorded during the first test (feet together) were found to be statistically correlated with their respective values calculated from the data recorded during the second test (feet apart): a statistically significant linear relation was found for the total group of participants ($r^2 = 0.35$; $p < 0.01$).

A statistically significant negative linear relation was found between age and performance at competition ($r^2 = 0.18$; $p < 0.05$) for the total group of participants.

Comparison between rifle and pistol shooters – Table 1

The senior rifle group obtained significantly higher points at competition ($Z = 3.63$; $p < 0.001$).

First test (feet together)

No significant differences were found between rifle and pistol shooters regarding a) total COM areas ($F_{1,25} = 1.49$;

Table 1. Score obtained at competition, body sway velocity and total COM areas during the tests of feet together and feet apart (20 seconds): groups of pistol and rifle Olympic shooters. N: number of participants. The results are expressed as mean ± standard deviation

	pistol (N = 22)	rifle (N = 6)
Score at competition (points)	549.17 ± 14.96	581.33 ± 8.62
Total COM Area ($m^2 \times 10^{-6}$) feet together	119.31 ± 47.02	96.70 ± 46.73
Total COM Area ($m^2 \times 10^{-6}$) feet apart	61.08 ± 27.36	33.52 ± 17.89
Average COM Velocity (m/sec x 10^{-3}) feet together	99.82 ± 11.05	96.73 ± 8.99
Average COM Velocity (m/sec x 10^{-3}) feet apart	96.66 ± 13.97	93.42 ± 7.24
Max. COM Velocity (m/sec x 10^{-3}) feet together	325.31 ± 39.24	318.87 ± 39.8
Max. COM Velocity (m/sec x 10^{-3}) feet apart	314.65 ± 38.12	281.62 ± 23.32

$p > 0.05$; $1 - \beta = 0.22$), with the covariable of age not having a statistically significant effect ($F_{1,25} = 0.45$; $p > 0.05$; $1\text{-}\beta = 0.09$) b) average COM velocities ($F_{1,25} = 0.58$; $p > 0.05$; $1 - \beta = 0.11$), with the covariable of age not having a statistically significant effect ($F_{1,25} = 0.23$; $p > 0.05$; $1 - \beta = 0.08$) and c) maximum COM velocities ($F_{1,25} = 0.03$; $p > 0.05$; $1 - \beta = 0.05$), with the covariable of age not having a statistically significant effect ($F_{1,25} = 0.00$; $p > 0.05$; $1 - \beta = 0.05$).

Second test (feet apart)

The total COM areas were found to be significantly less in the rifle group ($F_{1,25} = 6.7$; $p < 0.05$), with the covariable of age not having a statistically significant effect ($F_{1,25} = 1.3$; $p > 0.05$; $1 - \beta = 0.19$).

No significant differences were found regarding a) average COM velocities ($F_{1,25} = 0.41$; $p > 0.05$; $1 - \beta = 0.10$), with the covariable of age not having a statistically significant effect ($F_{1,25} = 0.14$; $p > 0.05$; $1 - \beta = 0.07$) and b) maximum COM velocities ($F_{1,25} = 2.88$; $p > 0.05$; $1 - \beta = 0.37$), with the covariable of age not having a statistically significant effect ($F_{1,25} = 0.03$; $p > 0.05$; $1 - \beta = 0.05$).

Comparison between elite and national level shooters –Table 2

The elite group obtained significantly higher points at competition ($Z = 1.93$; $p < 0.05$).

First test (feet together)

The average COM velocity of the elite group was found to be significantly inferior ($Z = 1.97$; $p < 0.05$).

No significant differences were found regarding a) total COM areas ($Z = 0.26$; $p > 0.05$; $1 - \beta = 0.09$) and b) maximum COM velocities ($Z = 1.38$; $p > 0.05$; $1 - \beta = 0.32$).

Second test (feet apart)

Significant differences were found, with the elite group having a) less values of the total COM areas ($Z = 2.36$; $p < 0.01$) b) less average COM velocities ($Z = 2.06$; $p < 0.05$) and c) less maximum COM velocities ($Z = 2.17$; $p < 0.05$).

Taking into account that only one elite shooter was tested on the same day of competition, and in order to assure that the differences found were not related to the differences in the stress levels before competition, the analysis of the total COM area was repeated including only the shooters tested on the day just before competition. As before, no significant differences were found for the first test ($Z = 0.70$; $p > 0.05$) while significant differences were found for the second test ($Z = 2.45$; $p < 0.01$).

Finally, for the pistol shooters only, no significant relation was found between the calculated total COM areas and score obtained at competition, neither during the first test ($r = 0.13$; $p > 0.05$) nor during the second test ($r = 0.14$; $p > 0.05$).

Discussion

Body sway variables have been compared between shooters of two disciplines, rifle and pistol, in contrast to most existing studies that examine the shooters body sway within one discipline [3, 4, 8, 13, 16, 25]. In order to this comparison to be achieved it was assured that the same percentage of participants was tested in both groups on the day of the competition and on the day before (11 pistol

Table 2. Score obtained at competition, body sway velocity and total COM areas during the tests of feet together and feet apart (20 seconds): groups of elite and Spanish national level. N: number of participants. The results are expressed as mean ± standard deviation

	Spanish national (N = 24)	Elite (N = 4)
Score at competition (points)	552.56 ± 17.06	576.25 ± 20.76
Total COM Area ($m^2 \times 10^{-6}$) feet together	116.55 ± 50.40	101.95 ± 14.02
Total COM Area ($m^2 \times 10^{-6}$) feet apart	59.41 ± 27.43	29.73 ± 13.80
Average COM Velocity (m/sec x 10^{-3}) feet together	100.55 ± 10.17	89.7 ± 6.69
Average COM Velocity (m/sec x 10^{-3}) feet apart	97.31 ± 12.71	83.68 ± 6.61
Max. COM Velocity (m/sec x 10^{-3}) feet together	328.52 ±37.37	295.55 ± 39.71
Max. COM Velocity (m/sec x 10^{-3}) feet apart	313.76 ± 35.79	270.68 ± 30.10

and 4 rifle shooters were tested on the day of competition, just before competing and 11 pistol and 2 rifle shooters were tested one day before competing).

According to the analysis, no significant differences exist regarding average/maximum COM velocities between the shooters of the two disciplines. Rifle shooters have been, however, shown to have significantly less total COM areas than pistol shooters, while standing quietly with feet apart. This result can be due to the specific (greater) necessities of the rifle discipline: the target dimensions are much smaller and therefore their body sway has a greater impact on the result, given the clear link between body sway and movements of the rifle barrel [4, 8, 16]. It can also be due to a higher ability of the rifle shooters. These results could be important when it comes to advise novice shooters towards one discipline or the other.

The results of the study showed that rifle shooters perform better than pistol shooters. This result only serves to confirm the known differences between performance amongst different shooting disciplines, which are due to the different techniques, guns and types of supportive clothing [1]. It should be emphasized that, in order to avoid any influence of supporting clothing on performance, the tests of this study were performed barefoot and without the special trousers and jackets that are officially used by the shooters during competition.

Regarding now the comparison between elite and national level shooters, no control of the percentage of participants tested in both groups on the day of the competition and on the day before was possible, due to the limited number of participants. For this reason the respective analysis was repeated excluding the participants who were tested on the exact day of competition (please refer to the Results section).

Elite shooters have been shown to have significantly less total COM areas and less average/maximum COM velocities at the position of standing quietly with feet apart. This result is in accordance with previous studies in rifle [8], pistol, [11] and running target [17, 25] shooting, and can be interpreted in two ways: it is either the result of elite training or it suggests that elite shooters were actually born with higher abilities to minimize body sway. It should be emphasized though, that, due to the limited sample of elite shooters that participated in this study, this is not a conclusion but a hypothesis that is to be examined in the future.

At the position of standing quietly with feel placed together, elite shooters have been shown to have significantly less average COM velocities, but statistically the same total COM areas and maximum COM velocities than national level shooters. These results can be explained taking into account that the position with feet apart approximates the shooting position, while the position with feet together is unrelated. Other authors who used testing positions similar to the shooting position also report significant differences between shooters of different level [10]. The statistical power of the results of the present study is, however, relatively low, due to the inherent limitations of the testing procedure, so it should be noted that no concrete conclusions can be drawn regarding the testing positions.

No significant relation was found between performance at competition and total COM areas. The calculations that leaded to this conclusion were performed only on the data of the pistol group, as such an analysis on the total group of participants would not be statistically valid. This result is in accordance with some existing studies [3,4] but in contrast to others [15, 24]. As no consensus exists in the existing literature regarding this issue, the present study suggests that the body sway should not be used as the only variable to predict performance in Olympic shooting. Other factors that determine the overall performance of a shooter such as the stability of the rifle barrel [16] or the time of the shooting decision [12, 24, 29] or the precision in pulling the trigger, should be also taken into account in order to make predictions of performance in Olympic shooting. As a further result, no significant relation was found between age and total COM areas, or average/maximum COM velocities.

It should be emphasized that, while most existing studies are based on data recorded under laboratory conditions (using specific pistol shooting tests [3] or specific rifle shooting tests [8, 16]) or during training conditions (using specific and non specific rifle shooting tests [18]), the tests of the present study were performed under competition conditions. However, this fact also poses the inherent limitation of small number of participants, which in cases results to lack of statistical power in the results (see discussion above). The low number of elite participants in the study is also a cause of limitation, a problem which is however hard to overcome, especially when the data collection is carried out under competition conditions. It should be noted here, however, that the present study's criterion for considering a shooter's level as elite is much stricter than other studies which consider as elite the best national level shooters. In the present study the term elite refers to shooters who have entered the finals in European or world championships, or world cups, which implies that an elite shooter in the present study is one of the eight best shooters in Europe or in the world.

To summarize, the present study concludes that:

(a) senior male Olympic rifle shooters have less body sway than senior male Olympic pistol shooters
(b) elite Olympic shooters have less body sway than national level shooters

(c) easy to carry out, non-specific body sway tests like the ones described in the present study could be used during the selection process of novice shooters and advice can be given to novice shooters towards a specific discipline according to their skills.

References

1. Aalto H., I. Pyykkö, R. Ilmarinen, E. Kähkönen, J. Starck (1990) Postural stability in shooters. *ORL J. Otorhinolaryngol. Relat. Spec.,* 52: 232-238.
2. Baca A., P. Kornfeind (2012) Stability analysis of motion patterns in biathlon shooting, *Hum. Mov. Sci*., 31(2): 295-302.
3. Ball K.A., R.J. Best, T.V. Wrigley (2003a) Inter-and intra-individual analysis in elite sport: pistol shooting. *J. Appl. Biomech*., 19: 28-38.
4. Ball K.A., R.J. Best, T.V. Wrigley (2003b) Body sway, aim point fluctuation and performance in rifle shooters: inter – and intra-individual analysis. *J. Sports Sci*., 21: 559-566.
5. Burden J., D. Faires (2005) Numerical analysis. Brooks Cole.
6. Caron O., P. Fontanari, J. Cremieux, F. Joulia (2004) Effects of ventilation on body sway during human standing. *Neurosci. Lett*., 366(1): 6-9.
7. Eng J., D. Winter (1993) Estimations of the horizontal displacement of the total body centre of mass: considerations during standing activities. *Gait Posture*, 1(3): 141-144
8. Era P., N. Konttinen, P. Mehto, P. Saarela, H. Lyytinen (1996) Postural stability and skilled performance-a study on top-level and naive rifle shooters. *J. Biomech*., (29): 301-306.
9. Goodman S., A. Haufler, J.K. Shim, B. Hatfieldd (2009) Regular and Random Components in Aiming-Point Trajectory During Rifle Aiming and Shooting. *J. Mot. Behav*., (41): 367-384.
10. Gulbinskienė V., A. Skarbalius (2009) Peculiarities of investigated characteristics of lithuanian pistol and rifle shooters´ training and sport performance. *Ugdymas Kuno Kultura*, 21.
11. Herpin G., G.C. Gauchard, A. Lion, P. Collet, D. Keller, P.P. Perrin (2010) Sensorimotor specificities in balance control of expert fencers and pistol shooters. *J. Electromyogr. Kinesiol*. (20): 162-169.
12. Konttinen N., D. Landers, H. Lyytinen (2000) Aiming routines and their electrocortical concomitants among competitive rifle shooters. *Scand. J. Med. Sci. Sports*, 10: 169-177.
13. Konttinen N., H. Lyytinen, J. Viitasalo (1998) Rifle balancing in precision shooting: behavioral aspects and psychophysiological implication. *Scand. J. Med. Sci. Sports*, 8: 78-83.
14. Krasilshchikov O., E. Zuraidee, R. Singh (2007) Effect of general and auxiliary conditioning on specific fitness of young pistol and rifle shooters. *Asian J. Exerc. Sport Sci*., 4: 1-6.
15. Mason B., L. Cowan, T. Gonczol (1990) Factors affecting accuracy in pistol shooting. *Excel*, 6: 2-6.
16. Mononen K., N. Konttinen, J. Viitasalo, P. Era (2007) Relationships between postural balance, rifle stability and shooting accuracy among novice rifle shooters. *Scand. J. Med. Sci. Sports*, 17: 180-185.
17. Mononen K., J. Viitasalo, P. Era, N. Konttinen (2003) Optoelectronic measures in the analysis of running target shooting. *Scand. J. Med. Sci. Sports*, 13: 200-207.
18. Niinimaa V., T. McAvoy (1983) Influence of exercise on body sway in the standing rifle shooting position. *Can. J. Appl. Sport Sci*., 8: 30.
19. Pellegrini B., F. Schena (2005) Characterization of arm-gun movement during air pistol aiming phase. *J. Sports Med. Phys. Fitness*, 45(4): 467-475.
20. Pinsault N., N. Vuillerme (2009) Test-retest reliability of centre of foot pressure measures to assess postural control during unperturbed stance. *Med. Eng. Phys*., 31: 276-286.
21. Reinkemeier H., G. Buhlmann, M. Eckhardt, C. Kulla, U. Linn (2006) Air rifle shooting: fitness – technique – 3-positions – supported – movement sequences – rifles – aiming paths – exercises – psyche – training – coaches. Dortmund, Verl. MEC 202.
22. RFEDETO (2009) General Technical Regulations for all shooting modalities – Reglamento Técnico General para todas las Modalidades de Tiro. Madrid: Real Federación Española de Tiro Olímpico.
23. Su F.C., W.L. Wu, W.D. Lee (2000) Stance Stability in Shooters. *J. Med. Biol. Eng*., 20(4): 187-192.
24. Viitasalo J., P. Era, N. Konttinen, H. Mononen, K. Mononen, K. Norvapalo, E. Rintakoski (1999) The posture steadiness of running target shooters of different skill levels. *Kinesiol.,* 31: 18–28.
25. Viitasalo J., P. Era, H. Mononen, K. Mononen, K. Norvapalo, E. Rintakoski (1998) Effects of footwear on posture control of running target shooters. *Coach Sport Sci. J*., 3: 3-6.
26. Winter D.A. (2004) Biomechanics and motor control of human movement. John Wiley & Sons Inc.
27. Zakynthinaki M.S., J.M. Milla, A. Lopez, C.A. Cordente, G. Rodriguez, G.M. Sillero, J. Sampedro (2010) Rotated balance in humans due to repetitive rotational movement. *Chaos*, 20: 013118.
28. Zanevskyy I., Y. Korostylova, V. Mykhaylov (2010) Shot Moment in Optoelectronic Training in the Air-Pistol Shooting. *Int. J. Sport Sci. Eng*., 4(2): 67-78.

29. Zatsiorsky V., A. Aktov (1990) Biomechanics of highly precise movements: the aiming process in air rifle shooting. *J. Biomech*., 23: 35-41.
30. Zatsiorsky V., M. Duarte (2000) Rambling and trembling in quiet standing. *Motor Control*, 4(2): 185-200.
31. Zok M., C. Mazzà, A. Cappozzo (2008) Should the instructions issued to the subject in traditional static posturography be standardised? *Med. Eng. Phys*., 30(7): 913-916.

Received 17.01.2014
Accepted 17.06.2014

This study was supported by the Consejo Superior de Deportes (Spain) as well as the Federación Española de Tiro Olímpico y la Federación Madrileña de Tiro Olímpico (Spain).