DOES THE SITTING POSITION INFLUENCE CLAY TARGET SHOOTING PERFORMANCE IN ATHLETES WITH A MOTOR IMPAIRMENT?

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Olympic trap clay target shooting (CTS) is currently performed by motor impaired individuals (MII), but not yet included in the International Paralympic Committee endorsement. This study aimed at supporting the development of a classification model that divides athletes competing in standing and sitting postures. Two groups of 5 standing and 5 sitting MII athletes were recruited for an instrumented CTS task execution. During competition, sitting athletes showed a lower rate of success with respect to the standing ones only for targets requiring wider ranges of motion, possibly due to fatigue. Their predominant use of upper body movements implies an adapted technique to reach a good performance, testified by a smoother movement, a lower peak accelerations at the gun tip, a smaller range for all absolute and relative rotations, and a different muscle activity.

KEYWORDS: Paralympic classification, clay target shooting, inertial measurement unit, surface electromyography.

INTRODUCTION: Olympic trap clay target shooting (CTS) consists of a complex sequence of minute movements performed in less than 1 second aimed at killing flying clay targets thrown at varying speeds, angles and elevations in a randomized order. CTS is currently performed by individuals with a motor impairment (MII), who compete standing or sitting on a wheelchair according to the severity of their lower limb impairment. CTS is not, however, included in the shooting sport events practiced under the International Paralympic Committee (IPC) endorsement which requires the definition of a selective classification system including: 1) the eligible types of impairment to participate; 2) the minimum impairment severity to be eligible; 3) the classification model (Tweedy and Vanlandewijck, 2011). This model states a set of classes of competition and allows to assign each MII to a specific one, taking into account the extent of activity limitation occurring in practicing CTS to minimize the impact of eligible impairments on the outcome of competition. In this way, a link is created between impairment and performance and an athlete who improves his/her performance through effective training will not be moved to a class with athletes who have less activity limitation, but will be rewarded by becoming more competitive within his/her class. To optimize classification validity, evidence-based methods are required that allow to develop and evaluate valid measures of sport-specific performance, and to assess the relative strength of association between measures of impairment and sports performance (Tweedy et al., 2014).
CTS technique has been analysed so far in able-bodied shooters, either in laboratory both using a shooting simulator (Swanton, 2011) or simulating the CTS activity in laboratory (Bernardi et al., 2013), and in field conditions (Causer et al., 2010). The following key factors for performance of top level athletes have been identified: 1) the time elapsed between the clay target release and the shoot (*shooting time*): usually the target is hit 40-50 meters distant from the athlete and within 0.5-0.9 s respectively for central and lateral shots (Causer et al, 2010; Swanton, 2011), since it moves away from the athletes, the shorter the shooting time the easier it is to hit it; 2) smaller ranges of motion (ROMs) and velocity peaks of the *gun movements; 3)* different *timing* for the trigger pull and a shorter movement time of the gun (Causer et al., 2010); 4) a *smooth movement* can result in a successful performance, as

demonstrated in a sport task similar to CTS (golf swing, Choi et al, 2014); 5) *body and gun stability*: the athletes' ability to stabilize themselves before the call for release can be of paramount importance for performance (Swanton, 2011). Pelvis rotation have been shown to account for about 70% of the total ROM of the gun (Bernardi et al., 2013), for both central and lateral shots (simulating targets shoot at 45 deg from the trap).
Differences in CTS performance between athletes competing seated on a wheelchair (Si) and standing athletes (St) has been investigated on in international MII CTS events involving 33 St and 24 Si athletes. The St athletes had the same total CTS experience as Si, but a significantly higher performance score (Bernardi et al., 2014). Since the Si athletes can carry out the required ROM only with the upper part of the body, it can be hypothesized that they adapt their key parameters up to the limit set by their impairment. Based on these results, this research group proposes that two separate medal events are set for St and Si athletes in Paralympic competitions. This study aimed at providing data and evidences to support the development of a classification model, to be used at Paralympic level, that divides athletes accordingly. The impact of the sitting position on CTS performance was assessed on a subset of the above-mentioned MII CTS athletes, using biomechanical or electromyographic parameters to find possible technical explanation of the performance differences between athletes competing in these postures.

Table 1 Median and inter quartile range for the anagraphic, anthropometric and sportive characteristics of the standing (St) and sitting (Si) athletes. Significant differences (p<0.05 or p<0.01) are reported with the symbol * or **, respectively.

	age (y)	mass (kg)	height (m)	Y_s (y)	Y_i (y)	h_t	MF	TS%	PS%	PS_F%	PS_B%	PS_T%
St (N=5)	52 [9]	94 [15]	1.75 [0.04]	16 [13]	14 [5]	4 [2]	303 [2]	80 [28]	85 [5]	72 [12]	83 [17]	100 [38]
Si (N=5)	55 [12]	90 [12]*	1.75 [0.09]	8 [3]	8 [3]	4 [2]	212 [9]**	40 [10]**	77 [17]	68 [7]**	67 [33]	75 [38]**

METHODS: Five St and 5 Si athletes were recruited to be submitted to an instrumented test aimed at assessing muscular activations and movement velocity and acceleration of the upper part of the body during actual CTS task execution. These athletes, all shooting with the right arm, were selected among those who competed in the final phases of the last four international competitions to limit differences due to performance levels, and had the same age and training status (training hours per week, h_t), years of experience in CTS, in general (Y_s) and as impaired shooters (Y_i) (Table 1). The athletes' performance was assessed as the percentage of the clays hit in the controlled test (on a total of 10, TS%), in the last four final competitions (PS_F%) and detailed in the last qualification competition (on a total of 75, PS%, and on the total of 6 targets at maximal range for barrel, PS_B%, and 8 for trigger side, PS_T%). Prior to start data acquisition, informed consent of the participants was obtained and their total motor functionality (MF) score to describe their impairment level assessed (Table 1).
Experimental test*:* Each athlete was requested to perform the procedures for "gun loading", the shooting task and the "gun unloading", from the same shooting stand, for 10 targets in a random order, 5 thrown in the extreme barrel side (around 45 deg) and 5 in the extreme trigger side (around 45 deg), using only one bullet as in the final competitions. The time interval between two consecutive targets was 60 s. To assess the interval time from target call to shot (reaction time) and assess the shooting success, two high definition video-cameras (SONY HDR-FX7E, Japan) were located lateral and posterior to athletes.
Electromyographic measurements: after proper skin preparation, two Ag/AgCl electrodes with a disc radius of 10 mm were placed 20 mm apart on the bellies of upper trapezius (C3 level), lower trapezius (T10 level) and deltoid muscles on both sides. The ground EMG reference was placed on the no-dominant wrist. Hence, the EMG signals were recorded with

a 16 channel telemetry electromyographer (PocketEMG®, BTS Bioengineering, Italy), at sampling rate of 2000 sample/s and band passed (0.1-500Hz).

Biomechanical measurements: Four synchronized magnetic inertial measurement units (MIMU) (Opal, APDM Inc., Oregon, USA) were used to collect 3D data of acceleration, angular velocity and magnetic field (128 sample/s; ±2g, ±1500°/s, ±600μT of full-range). Four MIMUs were positioned at sacrum (L5) and trunk (T1 vertebra) levels, on the acromion and the gun stock, at a distance of 0.65 m from the gun tip.

Data Processing*:* all analyses were performed using Matlab® (MathWorks Inc., MA, US). For the MIMU data, gyro bias was compensated and gravity acceleration removed. Acceleration and angular velocity components recorded for the gun were low-pass filtered using a 4th order Butterworth filter ($f_{cut\text{-}off}$ = 20 Hz) up to 20 frames from the shot. Based on rigid body mechanics, inertial data on the gun tip were estimated from the spline derivation of the angular velocity at the gun barrel. The shot instant was identified, for MIMUs, as the peak of the antero-posterior acceleration of the gun and, for EMG data, as a sharp peak due to the shotgun recoil, visually identified on shoulder muscle signal at the gun side. The following elements were analysed. *In the preparatory phase:* trunk stability before the call [$S_{g0.5}$, 96% of confidence interval of the acceleration value in the time interval 0.5 s, preceding the call instant, computed at both the gun tip and the trunk levels (Swanton 2011)]. *In the shooting phase (from call to shot):* movement smoothness [J^g_{RMS}, root mean square values of the jerk, i.e. derivative of the resultant of the gun acceleration]; gun movement description [peaks of resultant acceleration of the gun tip, a_{gP}, and of the angular velocity in the transverse, ω^t_{gP}, and sagittal planes, ω^s_{gP}]; subjects mobility [angular ranges of motion for pelvi, trunk, acromion and gun, $\Delta\theta_p$, $\Delta\theta_t$, $\Delta\theta_a$, $\Delta\theta_g$, obtained as integration of kinematic equations of the angular velocity, rotations computed as Eulero-Vectors with respect to the initial static position of the gun]; rotation strategy on the transversal plane [relative trunk – pelvis rotations, $\Delta\theta_{tp}$]; rigidity of the upper trunk [gun – acromion rotations, $\Delta\theta_{ga}$]; muscular activation [total sEMG power, *i.e.* sum of the RMS values calculated with a 10 ms moving window, scaled by the RMS value in the shot instant]. Parameter absolute values were considered when their sign depended on the shot side.

Statistical Analysis*:* Shapiro-Wilk normality test was performed on all parameters, most of which had non-normal distributions. Two non-parametric statistical analyses were performed: the Spearman coefficient, to search for significant ($p<0.05$) correlations among parameters; the Friedman test for repeated measures ($p<0.05$), for group comparison .

RESULTS: Sitting athletes had a less stable trunk in the static phase, but a smoother movement when shooting, which was paralleled by lower peak angular velocity in the sagittal plane for the gun, a smaller range for all absolute and relative rotations, and a different muscle activity, significantly higher in the deltoid and lower in the lower trapezius on the barrel side (Table 2). All athletes showed, in general, an obvious lower performance during the experimental test with respect to competition, but the sitting athletes had a lower performance during test and competition finals (Table 1). During the qualification phase, Si had a similar overall performance with respect to St, but had worse results for the trigger side targets, which require a wider ROM (Table 1). Therefore, the correlations of the qualification performance, obtained for all biomechanical parameters relative to the shooting phase except peak horizontal rotation velocities, can be considered predictive of the competition rate of success.

	$S_{g0.5}$ [m/s^2]	J^g_{RMS} [m/s^3]	a_{gP} [m/s^2]	ω^t_{gP} [deg/s]	ω^s_{gP} [deg/s]	$\Delta\theta_p$ [deg]	$\Delta\theta_t$ [deg]	$\Delta\theta_a$ [deg]	$\Delta\theta_g$ [deg]	$\Delta\theta_{tp}$ [deg]	$\Delta\theta_{ga}$ [deg]
St	0.3[0.8]	30[28]	12[7]	75[8]	22[8]	8[5]	14[7]	14[9]	21[3]	15[6]	24[7]
Si	0.2[0.7]	24[8]*	9[3]	74[10]	19[8]*	2[2]*	13[7]*	12[6]*	19[3]*	11[7]*	24[6]*

Table 2 *Standing and sitting athletes' main biomechanical parameters (median [inter-quartile range]). * significant differences between the groups*

DISCUSSION: The two groups can reach similar levels of performance, since sitting athletes developed an adapted technique to reach a good performance. However, their predominant use of upper body movements is more prone to fatigue, as evidenced by a significant lower performance in the finals and for the targets requiring a wider range of movement, both during qualification and test shoots. To hit these targets, the Si athletes must shoot earlier since they are unable to rotate to follow the target as much as the St athletes. Therefore the analysis of upper body movements is adequate to provide important information about the control of stability and performance and on how they change with an activity limitation of the lower body. Moreover, the significant correlations observed between body movements and the shot outcome can be used as a discriminating factor of the technical skill level.

CONCLUSION: This study provided data and evidences to support the development of a classification model, to be used at Paralympic level, that divides CTS athletes competing in standing and sitting postures. The hypothesis that two classes should be allowed for MII competing in this sport was confirmed by the significant differences between St and Si groups in several variables that can have an impact on performance as well as possibly being caused by the impairment. Given the type of variables that differentiated the two groups, it can be hypothesised that impaired muscle strength and limb deficiency could be considered as physical impairments with a potential to limit performance. These impairments might be considered as ‘eligible impairments’ for the sport of para-CTS, as traditionally done for shooting.

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