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ELECTROMECHANICAL DELAY IN A BALL RELEASE ACTIVITY WITH TIME- AND NON-TIME CONSTRAINED SITUATIONS PERFORMED BY BOCCIA PLAYERS

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ABSTRACT

Introduction: In Paralympic Sports is crucial to use tools to discriminate between sport classes. In our study it has been used the electromechanical delay (EMD) of finger extensors during ball realizing in two different situations: with/without command constrains to discriminate between BC1 and BC2 Boccia classes. Material and Methods: Twenty-eight recreational Boccia players eligible to play Boccia (BC1 and BC2 classes) took part in this study. A Surface Electromyography and a contact sensor were used to assess the electromechanical delay (EMD). The EMD variables calculated in both situations, with and without sound stimulus, were the average and the coefficient of variation (CV). Results: A negative correlation among average and CV in the without sound situation was obtained (cor. = -0.42; p = 0.025); and a positive correlation was obtained among the average scores in with and without sound situations (cor. = 0.63; p < 0.001). No significant differences were obtained within-situations comparisons and in the interaction classes*situations. Discussion: CV results suggest that EMD could be a variable to analyze the impact of the impairment in persons with cerebral palsy, but unfortunately did not have enough sensitivity in our study to discriminate between classes.

Key Words: cerebral palsy, boccia, classification, electromyography, electromechanical delay

RESUMEN

Introducción: En deporte Paralímpico es necesario usar herramientas que puedan discriminar entre las clases deportivas. En nuestro estudio se utilizó el retraso electromecánico de los músculos flexores de los dedos de la mano en la suelta de una bola de Boccia en dos situaciones: con y sin estímulo sonoro para discriminar entre las clases BC1 y BC2. Materiales y método: Veintiocho jugadores de Boccia de nivel recreativo de las clases BC1 y BC2 participaron en este estudio. Se utilizó electromiografía de superficie y un sensor de contacto para medir el retraso electromecánico (REM). Las variables del REM calculadas en ambas situaciones, con y sin estimulo sonoro, fueron el promedio de 10 ensayos y el coeficiente de variación (CV). Resultados: Se obtuvo una correlación negativa entre el REM promedio y el coeficiente de variación en la situación de suelta de la bola sin estimulo sonoro (cor.=-0.42; p=0.025). También se obtuvo una correlación positiva entre los promedios del REM en ambas situaciones (cor.=0.63; p<0.001). No se obtuvieron diferencias significativas entre situaciones y en la interacción de clases*situaciones. Discusión: Los resultados obtenidos en el CV sugieren que el REM podría ser una variable para analizar el impacto del impedimento en personas con parálisis cerebral durante la suelta de la bola, aunque en nuestro estudio no fue suficientemente sensible para discriminar entre las clases.

Palabras clave: parálisis cerebral, Boccia, clasificación, electromiografía, retraso electromecánico

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INTRODUCTION

Boccia is a precision sport, consisting of a number of rounds in which the players attempt to throw the game balls as close as possible to a target ball, which is called the *jack.* Boccia is governed, since 2013, by the Boccia International Sport Federation (BisFed) and is, together with Goalball sport for athletes with visual impairments, one of the two Paralympic sports that have no counterpart in the Olympic program.

Classification is a process by which athletes are assessed to determine the impact of their impairment on sport performance to ensure that there is fairness for all athletes within the sport. According to BisFed Classification Rulebook "the purpose of classification is to ensure that sporting success is a result of athlete's training, skill level, talent and competitive experience rather than their degree of impairment" (BisFed, 2013, p. 4). Thus, athletes are classified according to the extent of *activity limitation* resulting from their *impairment*.

The International Classification of Functioning, Disability and Health (-ICF-WHO, 2001) is currently the most widely accepted classification of health and functioning. In accordance with the ICF (2001), individuals with neurological impairments, including spastic hypertonia, dystonia, athetosis and ataxia (neuromusculoskeletal and movement related), are eligible to play Boccia (Tweedy, 2002; BisFed, 2013). These impairment types are associated with a broad range of conditions (e.g. cerebral palsy, traumatic brain injury, stroke…), so an athlete is eligible to compete if he/she has a neurological impairment with motor control or power impairments causing a permanent and verifiable activity limitation. This activity limitation refers to the difficulty of executing the sports-specific movements required in any particular sport (Tweedy & Vanlandewijck, 2011), being in our case, activities related mobility, concretely carrying and moving objects.

The new International Paralympic Committee Classification Code states that "International Sport Federations must develop sports-specific Classification Systems through multidisciplinary scientific research, and such research must be evidence-based focused on the relationship between impairment and key performance determinants" (IPC, 2015, p. 11). Sports classification for people with cerebral palsy (CP) has been in use for several years, nevertheless it is still complicated to fit these players into classification systems that are appropriate for other health conditions or disabilities (Khalili, 2004). The current Boccia classification rulebook (BisFed, 2013) provides and defines the athletes´ profiles to compete in this sport. People with CP can actually compete in classes BC1, BC2 or BC3. The basic differences between these three classes are: firstly, BC1 class is for athletes who are diagnosed with "spastic quadriplegia or athetosis, or who may have a mixed picture including those with severe ataxia" (BisFed, 2013, p. 25). Players with severe impairments affecting all four limbs and trunk, with a limited functional range of movement, functional strength, and/or limited coordination (particularly grasping and releasing activities) fit in this class. Secondly, BC2 players show moderate impairment of function, with possible limitation of active functional range of movement due to weakness, spasticity or lack of control, affecting the upper limbs and trunk. Finally, athletes classified in the BC3 class are "unable to consistently propel a Boccia ball with purposeful direction and velocity into the field of play, and they use an assistive device (ramp) to propel the ball onto the field of play with the help of an assistant" (BisFed, 2013, p. 33).

Surface Electromiography (SEMG) has been applied in the measurement of hand activities (Ahmad Nadzri, Ahmad, Marhaban, & Jaafar, 2014) and in the diagnosis of childhood hypertonia (Sanger, 2008), although surface EMG is rarely used to assess the activation and muscle coordination in upper limbs in people with CP (Xu, Mai, He, Yan, & Chen, 2015). However, the study of electromechanical (EMD) delay in persons with CP is very limited in the scientific literature (Granata, Ikeda, & Abel, 2000), and no studies has been conducted with Boccia players. From a classification point of view, hands and upper limbs functions (e.g. ball releasing and grasping) are key factors for classification decision making, i.e.: to decide if an athlete belongs to one class or another, BC1, BC2 or BC3.

This paper will analyze some aspects of the boccia throwing conducted by players with cerebral palsy belonging to BC1 and BC2 sport classes, with focus on the assessment of the electromechanical delay of the fingers extensors during a ball release. Because a common classification test performed by classifiers is to request players to release the ball after a verbal command, we evaluate the electromechanical delay performing the ball release with and without command constraints, in order to check the influence on the activity performance.

METHOD

Participants

Twenty-eight recreational Boccia players (14 men and 14 women) eligible to play Boccia under the BisFed rules took part in this study (41.23 ± 14.48 years). Ten players belonging to BC1 class (4 men and 6 women) and eighteen players (10 men and 8 women) belonging to BC2 class. Athletes under treatment with botulinum toxin in the last 6 months and/or surgery on the upper extremity in the last 5 years were excluded from the study. BC3 players were also excluded from our study due to their severe impairment to grasp and release a ball. Written informed consent was obtained from each participant prior testing. The study was approved by the Ethics Committee of the Miguel Hernández University in accordance with the Declaration of Helsinki.

Instrumentation and Data Collection

A Surface Electromyography (SEMG) and a contact sensor were used to assess the electromechanical delay (EMD) (figure 1).

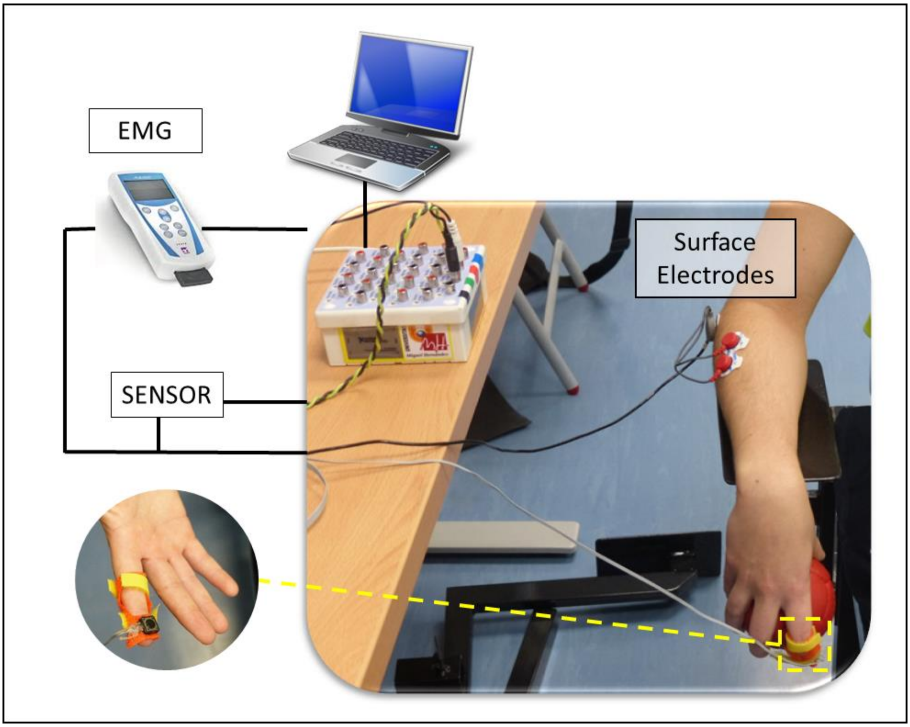

FIGURE 1: Schematic illustration of the protocol.

The electromyographic activity was recorded with surface electrodes placed over the *extensor carpi radialis* (ECR) according to Seniam Guidelines (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). The signal (AMT8-8, Bortec Biomedical, Calgary, Canada, with a CMMR of 115 dB at 60 Hz, and input impedance of 10 GΩ) were collected and amplified to produce approximately ± 2.5 V, and converted at 1024 Hz. The Raw EMG signals were rectified (full wave) and low pass filtered (second order single pass Butterworth) with a cutoff frequency of 2.5 Hz.

The contact sensor was a push button which closed an electrical circuit changing the voltage from 0 V to 5 V. At the moment that participants caught the ball the push button was pressed, and the circuit was closed (5 V). When participants dropped the ball the circuit was opened and the voltage changed from 5 to 0 V. This system allowed us to detect and monitoring the first apparent movement performed by the participant dropping the ball.

Through the synchronization of both signals using the Labview software (Version 2.04, National Instruments, Texas, USA), the EMD data was inferred (in milliseconds -ms-). The EMD during any trial was the time between the onset of the ECR EMG response and the onset of the fingers movement when participants dropped the ball (figure 2).

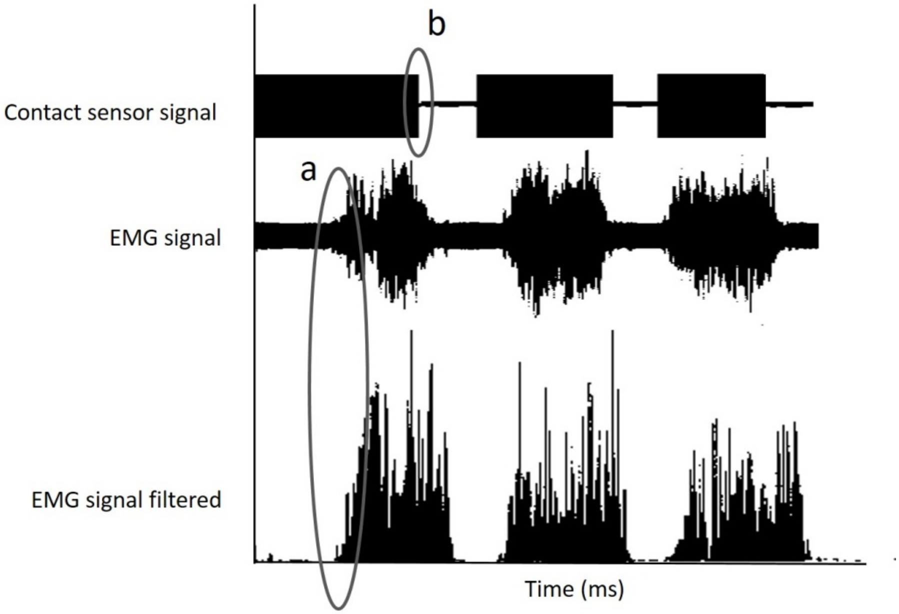

FIGURE 2: EMD detection: a. the onset of the ECR EMG response; b. the first apparent movement the first apparent movement when participants dropped the ball. EMD = time between a and b.

The algorithm used to determine the point of the EMG onset was the mean of a specified number of samples exceeding the baseline activity level by three standard deviations, for a minimum of 25 ms from the baseline. The point at which the EMG signal exceeded this preset threshold was considered the EMG onset (Cowan, Bennell, & Hodges, 2000). This value was confirmed through visual inspection by an experienced examiner.

Procedure

The area, where the EMG sensor was placed, was shaved with a disposable razor and vigorously abraded with a swab dipped in alcohol to remove dead skin cells and oils from the surface of the skin before placing the electrodes on the muscle belly (Hermens et al., 2000). The EMG sensor was attached with double sided sticky tape (BSN Medical Strappal). A conductive gel was also used to inhibit the effects of excessive sweating during the long testing periods. The reference electrode was placed on the humeral medial epicondyle. The contact sensor was placed on the fingertips of finger which was more functional to catch the ball, usually the forefinger.

All participants were sitting in a chair designed specifically to perform this protocol. This chair allowed us to immobilize the trunk of the participant and place the forearm in neutral position on a horizontal support (figure 1). The elbow was placed as close as possible to 90º of flexion, although some athletes were not able to reach that to position due the spastic hypertonia presented in their arms. The shoulder was slightly abducted and the wrist flexed to keep the ECR relaxed as much as possible.

Participants were asked to drop a Boccia ball and perform two series of 10 trials using their throwing hand. Each series was performed under two different situations: i) with a sound stimulus to drop the ball; and ii) participants did not have any external stimulus and they had to drop the ball when they wanted. One test trial was allowed prior each series to ensure that the task was well understood. An official Boccia ball was used (Boccas -medium hardness-, Portugal; weight = 281 gr; circumference: 274 mm). A target (size = 1.5 x boccia ball circumference) was placed, on the floor, perpendicularly to the throwing hand.

Statistical Analysis

The EMD variables calculated in both situations, with and without sound stimulus, were the average, standard deviations (SD) and the coefficient of variation (CV) using the next formula: $CV = (SD/Mean) \cdot 100$ (Atkinson & Nevill, 1998). The normality of the studied variables was evaluated using the Kolmogorov-Smirnov test with the Lilliefors correction.

The strength of association between the trials average and the CV in both situations was assessed using a Pearson correlation (r). To interpret those results the threshold values for Pearson product-moment used by Salaj and Markovic (2011) were used: low ($r \leq 0.3$), moderate ($0.3 < r \leq 0.7$) to high ($r > 0.7$). Repeated measures ANOVA analysis was used to detect differences between BC1 and BC2 groups, among situations and the interaction between both variables (within- and between-groups).

Effect sizes (Cohen's *d*) above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered as large, moderate, small, and trivial, respectively (Cohen, 1988). Statistical analyses were conducted by SPSS (Version 20.0; SPSS, Inc. Chicago, IL), and *alpha* level was set at $p < .05$.

RESULTS

Normality distribution of the studied variables was assessed and parametric statistics were conducted. Table 1 shows the descriptive scores of the finger extensors EMD (mean ± standard deviation) for the average and coefficient of variation (CV) in both situations. The correlation analysis showed a moderate and negative significant correlation among mean and CV in the without sound situation (cor. = -0.42; p = 0.025). In addition, a moderate and positive correlation was obtained among the average scores in with and without sound situations (cor. = 0.63; p < 0.001). No significant correlations have been obtained among average and CV in the situation with sound or among the CV´s in both situations.

TABLE 1

Mean (M) and Standard Deviations (SD) for 10-trials average and Coefficient of Variation (CV) scores in without and with sound situations to release the ball.

	Without sound (M ± SD)		With sound (M ± SD)	
	Average	CV	Average	CV
BC1	52.9 ± 6.0	34.5 ± 8.1	55.2 ± 17.0	31.33 ± 10.2
BC2	55.5 ± 9.2	31.8 ± 9.9	57.3 ± 12.5	32.3 ± 15.8
Total	54.6 ± 8.3	32.6 ± 9.3	56.5 ± 14.1	31.9 ± 13.7

Repeated measures ANOVA showed no significant differences between groups, with trivial effect sizes in both situations, without sound (Average d = -0.17; CV d = 0.15) and with sound (Average d = -0.07; CV d = 0.04). No significant differences were also obtained within-situations comparisons and the interaction groups*situations.

DISCUSSION AND CONCLUSIONS

BisFed classification rulebook (2013) embraces the term spastic hypertonia and dystonia as eligible impairments for Boccia competition. Spasticity is a form of muscle overactivity associated with cerebral palsy (Brændvik & Roeleveld, 2012), which tends to predominate in the antigravity muscles, particularly in arms flexors, key muscles for the overhand throw action in Boccia. On the other hand, dystonia is resistance to passive movement that may be focal (affecting muscles of one limb or joint) or general (affecting the whole body).

Hand dysfunction in people with CP is related to unsatisfactory muscle recruitment during movement performance (Rose & McGuill, 2005). Recent studies with SEMG have studied elbow flexion and extension (Brændvik & Roeleveld, 2012) and wrist flexion and extension (Xu et al., 2015) in persons with hemiplegic CP. Brændvik and Roeleveld (2012) concluded that spasticity increases coactivation (concurrent activation of agonist and antagonist muscles around a joint) in the muscle antagonistic to the spastic one (Damiano et al., 2000; Elder, Kirk, & Stewart, 2003; Tedroff et al., 2008), although coactivation plays a minor role in muscle weakness in CP and does not limit force modulation (Ikeda Abel, Granata, & Damiano, 1998). In addition, Xu et al. (2015) demonstrated that children with hemiplegia presented an excessive coactivation of wrist flexors when using the affected hand. These authors indicated that the cocontraction ratio of the affected hand during gripping action was significantly higher than the unaffected hand, decreasing the movement efficiency and limiting the function of the affected hand. An excessive presence of this phenomenon could imply an inherent reciprocal action by the neuromuscular system and it can be treated as a form of muscle overactivity (Sheean & Mcguire, 2009).

Granata et al. (2000) stated that the EMD could be affected by muscle stiffness, especially in spastic muscles. In our study, during the ball releasing activity without sound stimulus, the significant and negative correlation among the 10-trials average and the CV it could also suggest an excessive muscle coactivation. EMD is primarily a measure of elastic stiffness (Sabido, Caballero, & Reina, 2014). The results of this study showed similar EMD values to other studies (Granata et al., 2000) where EMD was measured in lower limbs of CP participants. CV is a non-usual variable in EMD analysis but several authors (Yanci et al., 2014) have showed the importance of this variable to describe performance in CP population.

The Australian Spasticity Scale (Williams et al., 2008) is actually used to evaluate spastic hypertonia in Boccia players, consisting in a 0-to-4 ratio-scale. Thus, BC1 players should present spasticity grade 3 or above, while BC2 players should demonstrate spasticity grade 2-3 with or without athetosis. On functional assessment, the impact of the spasticity must be evident when assessing the release and the follow through (Bisfed, 2013). An athlete, who presents only hyperthonia and excessive muscles co-contraction, could show an increased EMD scores with lower CV due to stiffness/hyperthonia. Therefore, co-activation may both enhance and put limitations on motor performance; thereby it may also represent a motor control strategy in situations with a need of increased joint stability or improved movement accuracy (Gribble et al., 2003). On the other hand, an athlete with more athetoid or dystonic profile will increase his/her CV due to the involuntary movements with lower average scores because he/she is able to release the ball faster. This hypothesis could be supported by the correlation among EMD average and CV obtained in the without sound situation, in which athletes could decide the best moment to release the ball. The mixed pictures of hypertonia with/without athetosis and/or dystonia usually presented by BC1 and BC2 Boccia players could influence on the performance variability (e.g. release the ball), and it might be difficult to use EMD as a potential variable to discriminate between classes.

In competition, the time that players have to play all the balls is limited, being common to face compromised time-constrained situations to play the latest balls. According to Darainy and Ostry (2008), and Silva et al. (2009), stiffness modulation is assumed to vary with different tasks and environmental constraints. In our study, the lack of correlation among average and CV in the with sound situation (and also among CV´s) could be interpreted as a time-constrained task to release the ball impacting on player's performance. However, these findings must be interpreted cautiously because no significant differences were found between situations and the positive correlation among the EMD average scores in both tasks.

Since both BC1 and BC2 players usually have activity limitations in hand function and follow through, our results could be related with the coordination problems they usually present in their upper limbs (Roldán, Garcia-Vaquero, Mathee, Tweedy, & Reina, 2015). For example, in dystonic profiles, contractions are powerful and sustained and cause twisting or writhing of the affected areas, but the pattern is highly variable and contractions may be fast or slow (O'Sullivan, 2001). In conclusion, CV results suggest that EMD could be a variable to analyze the impact of the impairment in persons with CP, but unfortunately did not have enough sensitivity in our study to discriminate between classes.

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