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Methodology for obtaining kayak technique using a motion analysis system

Metodología para obtener la técnica de kayak utilizando un sistema de análisis de movimiento

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Biomechanics, kinematics, sEMG, sports analysis, technique analysis.

Palabras clave:
Biomecánica, cinemática, sEMG, análisis deportivo, análisis de la técnica.

Abstract

Movement analysis is known as the qualitative assessment of the musculoskeletal system during the execution of a motor task. This kind of analysis allows to define the technique of sports motor tasks. In this study we used a stereophotogrammetry camera system and surface electromyography on a healthy novice subject to describe her kayak paddling technique. We placed 14 mm reflective markers, and sEMG on six muscles of the upper body, and performed a manual muscle testing for each muscle before the trial. The subject performed the kayak paddle technique on a kayak ergometer, we recorded 45 seconds in the middle of a 10-minute dynamic trial. The data processing for the kinematic data consisted in: reconstructing the biomechanical model; filling the gaps of the trajectory; defining events of the motor task; calculating the range of motion of the joints. While the processing of the sEMG data consisted of obtaining the envelope and the definition of «on» and «off» of each muscle. The results show the paddle trajectory, the definition of muscle activation based on the on/off, the percentage of muscle activation, the range of motion for the joints. As the results show we were able to determine the kayak paddling technique and compare it to what has been previously published, i.e., the subject measured showed a shoulder rotation that is different to what has previously been reported in novice subjects, on the other hand the muscle activation of the dorsal and upper trapezius is similar to what has previously been reported.

Resumen

El análisis de movimiento es un método cuantitativo que evalúa el sistema musculoesquelético mientras realiza una actividad motora. Este tipo de análisis permite definir técnicas deportivas. Dentro de este estudio se utilizó un sistema de cámaras de estereofotogrametría y electromiografía de superficie en un sujeto sano para describir la técnica de paleo mientras realiza kayak. Al sujeto se le colocaron marcadores reflectivos de 14 mm, y electromiografía de superficie en seis músculos del miembro superior, previo a comenzar la prueba se realizó un manual muscular para obtener la fuerza isométrica máxima voluntaria de los músculos de interés. El sujeto realizó la técnica de kayak estando sobre un ergómetro durante 10 minutos, a la mitad de la prueba se grabaron 45 segundos. El procesamiento para los datos cinemáticos consistió en: reconstrucción del modelo biomecánico, rellenar los espacios e interpolar las trayectorias, definir los eventos dentro del gesto motor, calcular el rango articular. Por otro lado, el procesamiento de la señal de electromiografía consistió en obtener la envolvente y definir los momentos de «prendido» y «apagado» de los músculos. Los resultados muestran la trayectoria de los músculos, el porcentaje de activación de los músculos y el rango articular, los cuales se pudieron comparar con resultados previamente publicados, por ejemplo, nuestros resultados muestran una rotación en el hombro al momento de realizar el gesto motor, la cual no se encuentra en estudios previos, mientras que para la activación muscular el patrón para el dorsal y trapecio superior es similar.

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INTRODUCTION

Movement analysis is the assessment of an individual motion, whose objective is to gather quantitative information about the mechanics of the musculoskeletal system during the execution of a motor task; to fulfill this, it combines biomechanics principles, evaluation of kinematics and kinetics, and also it could use physiological variables such as surface electromyography (sEMG), electrocardiogram (EGC), VO2 exchange, and calorimetry among others. Kinematics is defined as the analysis of movement which involves measures of position, velocity, acceleration, and range of motion (RoM), the equipment use to perform this kind of analysis usually involves stereophotogrammetry cameras or Inertial Measurement Units (IMU's).[1,2]

The results obtained in a human motion analysis study helps to plan or assess the efficacy of a treatment in different types of patients such as cerebral palsy; spinal cord injury; stroke; knee osteoarthritis; among others. Specifically, in sports medicine, it can help in performance enhancement; injury prevention; and the definition or study of techniques.[1,3]

Technique definition for subjects without any experience in specific sports can be useful to determine the key differences between professionals and amateurs or novice players; also based on the technique of the subjects recommend specific exercises to help the subjects fulfill their capabilities i.e., kayak for postural control.

To analyze any technique, the first step is to define key events that would differentiate between phases, i.e., heel strike, foot off, kick, water-in, contact, etc. each phase will have a purpose according to the overall objective.

The aim of this paper is to apply a movement analysis methodology that will help determine the kayak technique in healthy novice subjects, this with the objective of using this methodology in subjects with spinal cord injury, since there has been done research in which subject's trunk control are trained using a kayak ergometer,[4] in the future the methodology created on this paper, will help to determine the technique, assess the subject abilities and help measure the differences that exist before and after therapy.

MATERIAL AND METHODS

Measurements were taken at the Movement Analysis Laboratory in the *Instituto Nacional de Rehabilitación «Luis Guillermo Ibarra Ibarra»*. The subject gave her written informed consent.

We recruited a healthy 30-year-old woman, with a height of 1.62 m and a weight of 57.6 kg. First, we placed on the subject sEMG sensors (Delsys IM, Massachusetts, USA) in shoulder and trunk muscles, for this study the evaluated muscles were: upper, middle, and lower trapezius; medium deltoid; erector spinae; mayor pectoralis; and external obliques. All muscles were placed bilaterally, for the trapezius and middle deltoid muscles we follow the guidelines provided by the Surface Electromyography for the Non-Invasive Assessment Muscles (SENIAM),[5] for the erector spinae and external obliques muscles we followed the methodology from Southwell et al.,[6] finally, for the major pectoralis muscle we followed the methodology from Creveaux et al.[7] Once the sEMG was placed a manual muscle test for each instrumented muscle was performed to obtain the maximum voluntary contraction (MVC) and be able to normalize the sEMG. To obtain kinematic information we placed on the subject 14 mm reflective markers following the guidelines and recommendations of the Plug-in Gait Full Body biomechanical model,[8] also we placed markers on each end of the paddle and middle to follow its trajectory.

Once the subject had the markers and sEMG placed, she was put on a kayak ergometer (SpeedStroke, KayakPro, Florida, USA), we place the paddle on the subject with 90º shoulder abduction and 90º elbow flexion, next the ideal movement and range of motion was explained, the subject had time to practice and in case there was a visible error in the movement it was corrected, once the subject felt comfortable with it, we recorded 45 seconds at the 5-minute mark of the movement in a 10-minute trial. All data was recorded using Nexus 12.2 (Vicon, Oxford, UK), for the kinematic data we used 6 Vantage and 8 Vero cameras connected to the system, the sEMG was synchronized using a LockLab from Vicon. The recording rate was set to 150 Hz, while the sEMG data was recorded at 2,000 Hz, Vicon does the synchronizing and signals interpolation and decimation.

After the trial ended the data post processing started in Nexus which consisted of labeling each marker placed on the subject, filling gaps with the different options provided by the software such as: spline filling, linear filling, cyclic filling, and pattern filling. A Woltring filter[9] was used to smooth the signal noise created by the markers, after that, PiG Dynamic pipeline was run to obtain each joint angle through the trial, after this, the data was exported to Visual3D (C-Motion, Maryland, USA).

In Visual3D the events for «water-in» and «water-out» were defined for each side based on the position of the markers placed on each end of the paddle. Once the events were defined, we calculated each joint range of motion and the cycle time. For all the files with sEMG (dynamic trial and each muscle MVC) we calculated for each channel the average and subtracted it from the original signal to remove any offset, after a high pass filter with cutoff frequency of 50 Hz, a Butterworth low-pass cutoff frequency of 500 Hz was removed, finally a moving RMS filter of 201 Window was performed.

Next for each MVC file (one per muscle) we obtained the maximum value; this value was used to normalize all sEMG data on the dynamic trial. After this, the methodology from De Luca[10] was followed, once the RMS was obtained the average was calculated to obtain the rest value (muscle-off), when the signal went above 15% the average value, we determined that the muscle went on, and when it went down that value the muscle went off.

RESULTS

The RoM calculated for each joint is shown in *Table 1*. With the defined events, we were able to obtain the cycle time (measure from «water-in» to «water-in» events) for the left side was 1.71 s, while for the right side was 1.70 s, also we could determine that the push phase (measured from «water-in» to «water-out» events) for the left side was of 0.86 s (50.30% of the cycle) and for the right side it was of 0.86 s (50.59% of the cycle).

In *Figure 1* we can see the trajectory of the end of the paddle on both sides made through the whole dynamic trial, and how the upper body and trunk move to create that trajectory, showing the joints and planes with more RoM, as we can see the trajectory followed by both sides tends to be oval for the left side and more circular to the right side, even there exists difference in trajectories, the only notable difference in the goniometry is found on the external-internal rotation of the shoulder, as it can be seen in *Figure 1F*.

For the muscle activation with the method used, we could determine the on-off of each muscle measured during the dynamic trial, this could be seen in *Figure 2*, in which we can see that the upper trapezius stays active the whole trial, the lower trapezius is active at 10% of the push phase through the half of the recovery phase, something similar happens to the trunk erectors, while the dorsal is only active in the push phase, the pectoral goes off only at the end of the push phase, and the external oblique is only active on the recovery phase. Finally, in *Table 2* we show the mean values of the muscles when they are in the "on phase" and the maximum value on this phase.

Table 1: Body range of motion when performing kayak on an ergometer.

	Bilateral parameters (°)	
	Left	Right
Shoulder Flex-Ext	69.51	75.03
Shoulder Abd-Add	86.68	83.95
Elbow Flex-Ext	96.25	99.69
Wrist Flex-Ext	51.52	59.50
Hip Flex-Ext	2.08	4.35
Knee Flex-Ext	1.75	3.87
Ankle Flex-Ext	1.31	2.11
	Axial parameters (°)	
Head rotation	11.88	
Spine Flex-Ext	6.12	
Spine rotation	33.07	

Flex-Ext = flexion-extension; Abd-Add = abduction-adduction.

DISCUSSION

With the quantitative information obtained from the human movement analysis equipment, we can describe the technique of a novice subject on a kayak ergometer.

The paddle trajectory that the subject had on the trial was an oval and circular form, with some rotation to the right, compared to the results presented by novice subjects in the work of Limonta et al.[11] and Fleming et al.,[12] we can see that there is indeed a difference, the results they showed had an oval form without the rotation that our subject presented. With this in mind, the trajectory on the left side for our subject was closer to the novice subjects that presented Limonta and Fleming, even though the subject is placed on a kayak ergometer with the paddle fixed to a pulley system the trajectories were not similar for both sides, and explain the differences in RoM internal-external rotation of the shoulder, shoulder rotation allows the paddle to go farther and create a more oval trajectory, which was the case for the left side *(Figure 1)*. For the RoM the average elbow flexion/extension is of 97.97° ± 1.72, which is similar to the intermediate subjects of

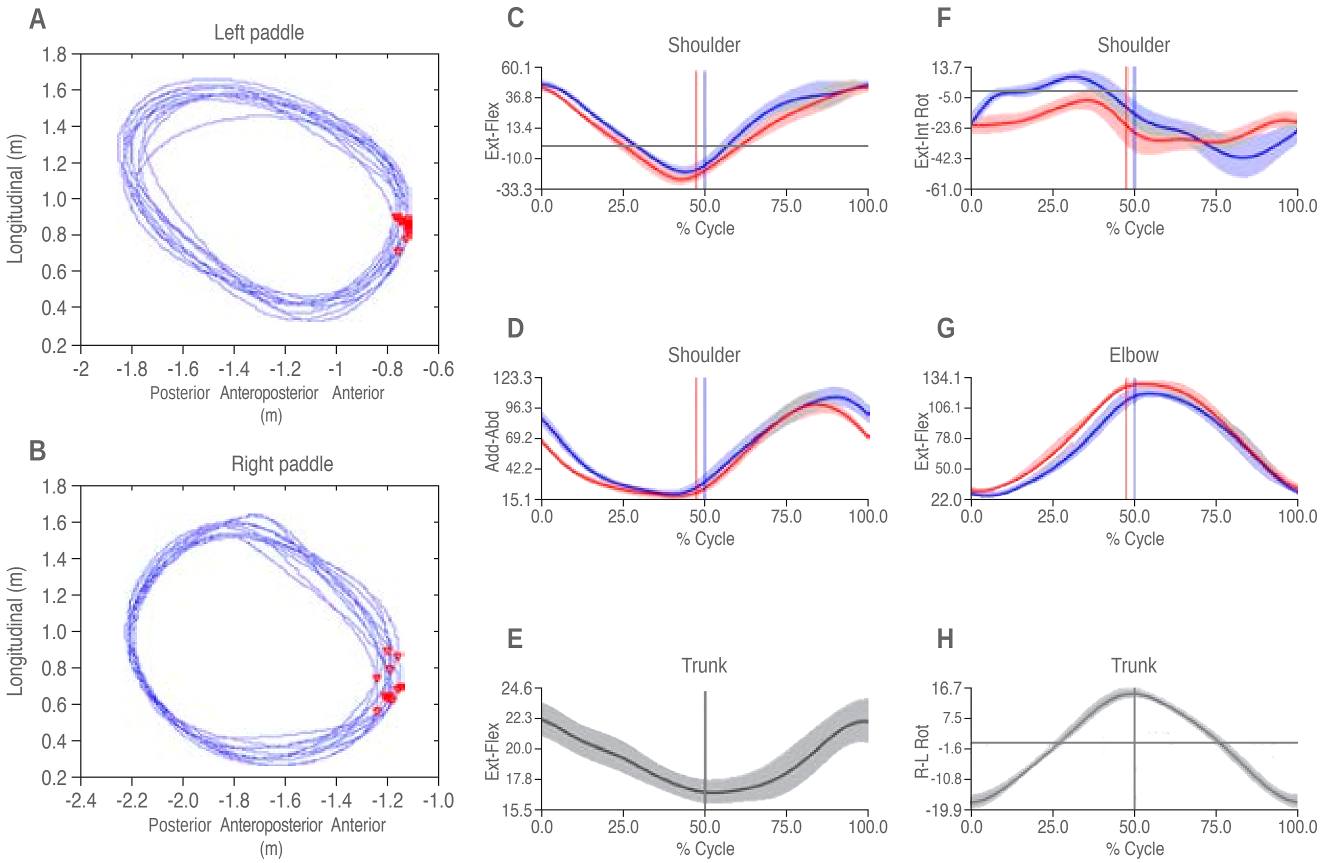

Figure 1: Upper body joint angles and paddle trajectory when performing kayak. Joint angle trajectories are shown in mean and standard deviation through a cycle from water-in to water-in events. For images **A** and **B)** is the sagittal plane for each side of the paddle, the red arrows show each «water-in» event in the dynamic trial; for images **C** through **H)** the vertical line indicates the «water-out» event, color blue is left, color red is right, black is appendicular body. Abbreviations: Ext-Flex = extension-flexion; Ext-Int Rot = external-internal rotation; Add-Abd = adduction-abduction; R-L Rot = right-left rotation. **A)** Left end of the paddle; **B)** right end of the paddle; **C)** shoulder extension-flexion; **D)** shoulder adduction-abduction; **E)** trunk extension-flexion; **F)** shoulder external rotation-internal rotation; **G)** elbow extension-flexion; **H)** trunk right-left rotation.

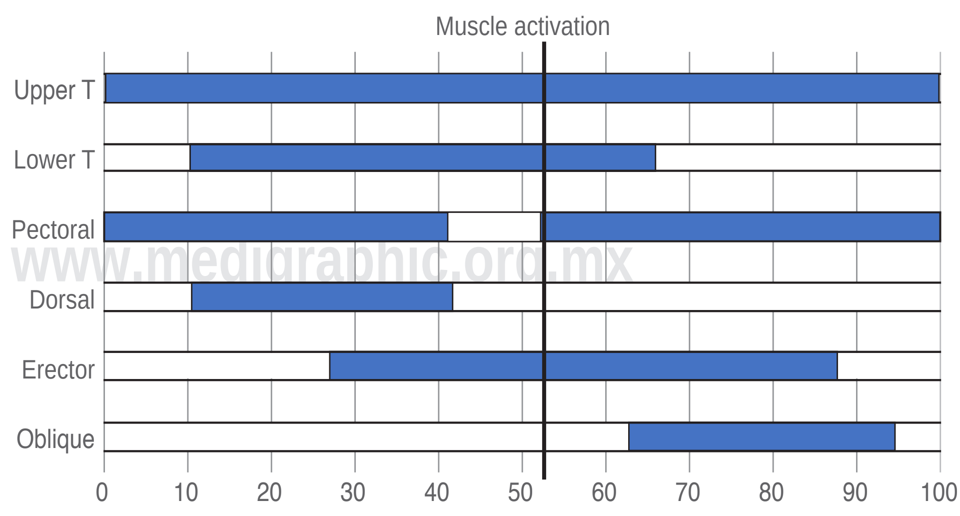

Figure 2:

Average muscle activation through the dynamic trial, bars in white show muscle off while bars in blue indicate muscle on, the vertical line at 50.86% of the cycle show the change from push phase (water-in to water-out events) to recovery phase (water-out to water-in events). Abbreviations: T = trapezius.

Table 2: Muscle values normalized to MVC.

	Muscle activation (%)	
	Mean	Max
Dorsal	16.08 ± 1.85	24.82 ± 5.00
Erector	16.25 ± 6.69	30.35 ± 7.31
External oblique	9.34 ± 2.87	62.47 ± 13.77
Pectoral	71.5 ± 20.61	105.24 ± 15.14
Upper trapezius	123.61 ± 10.66	200.41 ± 0.00
Lower trapezius	27.33 ± 4.15	46.68 ± 10.34

MVC = maximum voluntary contraction.

Limonta, overall the RoM showed on the whole cycle is similar to the novice subjects on the same study, which is expected since our subject learned that day the proper technique, in this study the knee RoM is also reported which for the novice subjects was of 24º ± 6, a value that is far from the one we obtained of 2.81º ± 1.06, it may seem that kayak is a gesture that uses only the upper body, but as it is reported by Limonta there exist movement at the knee which based on the subject position helps to move the pelvis which results in more upper body rotation. These results show that our subject is between a novice and intermediate kayak athlete, only taking into consideration the information provided by the kinematic equipment. With this information we could also obtain the asymmetry between sides, which could be useful for treatment or rehabilitation follow-up.

For the sEMG with the methodology used we were able to determine the moments the muscle goes from «off» to «on» and vice versa, and also what is the % of the MVC. Compared to the results presented by Brown et al,[13] we can see that our subject had a lower muscle activation based on the %MVC, the muscles that are presented in both works are dorsal and external oblique. Based on the graphs presented by Trevithick et al.,[14] we could see that the pattern activation for the dorsal and upper trapezius is the same as the one that we are reporting, this means that the muscles are being activated accordingly to perform the movement, which is why the trajectories and RoM are similar to what has been previously been reported.

CONCLUSION

With this work, we could demonstrate that with the proper kinematic movement analysis equipment, and the correct biomechanical models, muscle selection, and procedures we were able to describe the kayak technique of a healthy novice without training and compare it to the technique previously reported in the scientific literature.

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