LOWER LIMB EMG SIGNALS STUDY FROM DIFFERENT MUSCLES FOR POTENTIAL MYOELECTRIC PROSTHESES CONTROL

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Abstract

A Using previously designed portable EMG acquisition device and a specialized software EmgLab, a complete study of the EMG signals from different lower-limb muscles is made. The goal is to choose the most suitable signals for controlling myoelectric prostheses. During the study different motions are exercised: level walking, going up and downstairs.

1. INTRODUCTION

In individuals who have lost limbs, in order to recreate the movement of the limb with an active prosthesis, an estimation must be made based on other muscles used for particular movement. A detailed study must be performed to record the muscles activity in healthy individuals.

First we need to understand the biomechanics of human walking, as this information plays a crucial role in the design of such systems. A simplified diagram of human walking gait is shown on Fig.1 [1]

Note that the timing of the labelled events during the gait cycle is approximate, and varies across individuals and conditions. The human walking gait cycle is typically represented as starting (0%) and ending (100%) at the point of heel strike on the same foot, with heel strike on the adjacent foot occurring at approximately 62 % of gait cycle.

In general, the human leg can be thought of as a seven degrees of freedom structure, with three rotational degrees of freedom at the hip, one at the knee and three at the ankle. A description of the human anatomical planes as well as a kinematic model of the human leg in the sagittal plane, which is the dominant plane of motion during human locomotion.

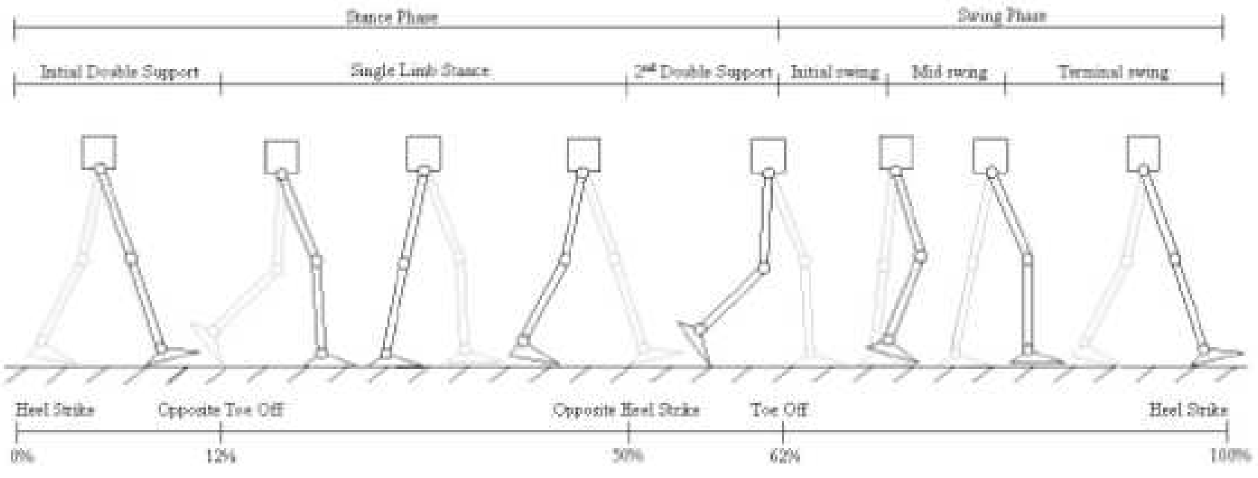

Fig. 1 Human Wlaking gait through one cycle

The positive motion in the sagittal plane is called flexion and the negative motion is called extension.

This is the plane and the motions an active EMG driven prosthesis will use.

Figure 3 show the biomechanics of a normal, healthy individual, showing joint angle for hip, knee and ankle flexion/extension motions during level-ground walking [2]. While walking data can differ some what across subject and condition, the qualitative nature of the curves remains similar [3].

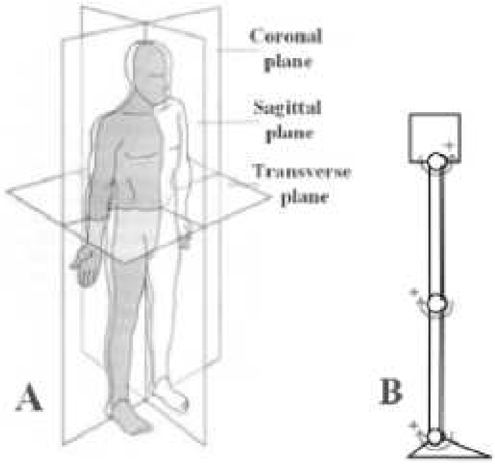

Fig. 2

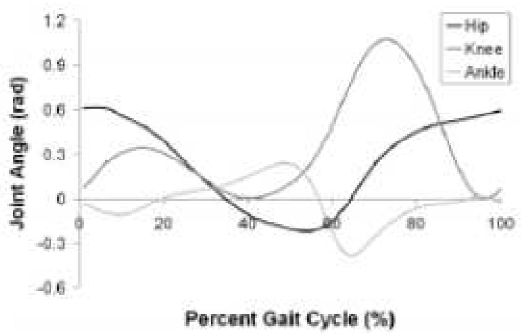

Fig. 3

To perform the study an specially designed EMG recorder was developed. It collects EMG data from surface electrodes at frequency of 2000Hz. Data is send via Bluetooth to a PC where it is processed by a specially developed software EmgLab.

In this software an algorithm is used to detect muscle contraction with a possibility to assess the level of contraction in real-time [4].

The algorithm is based on the Pan-Tompkins QRS detection algorithm. It has four stages in signal processing. Bandpass filtering to remove unwanted noise. Differentiation stage to emphasize the high frequency signal. Integration stage to make the result positive and further emphasize the large differences. The moving average smooth the multiple peaks from the squaring operation.

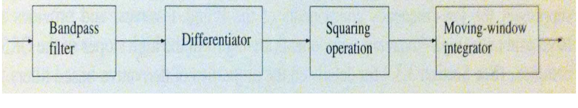

Fig. 4

There are many muscles involved in the gait cycle. We will turn our attention to the muscles of the upper leg and specifically the Quadriceps and the Hamstrings.

The quadriceps femoris (quads) is a large muscle group that includes the four muscles on the front of the thigh. It is the great extensor muscle of the knee, forming a large fleshy mass covering the front and sides of the femur. It is subdivided into four separate portions (heads), each with distinctive names. Rectus femoris occupies the middle of the thigh, covering most of the other three quadricep muscles. It originates on the ilium and is named from its straight course. The remaining three lie deep to rectus femoris, and originate from the body of the femur, which they cover from the trochanters to the condyles.

These muscles are powerful extensors of the knee joint. They are crucial in walking, running, jumping, and squatting. Because rectus femoris attaches to the ilium, it is also a flexor of the hip. This action is also crucial to walking or running, as it swings the leg forward into the ensuing step. The quadriceps (specifically the vastus medialis) plays the important role of stabilizing the patella and the knee joint during gait.

The hamstring refers to any one of the three posterior thigh muscles (semitendinosus, semimembranosus and biceps femoris) that make up the borders of the space behind the knee; or can refer to their corresponding tendons.The hamstring muscles flex (bend) the knee, while all but the short head of biceps femoris extend (straighten) the hip. The three 'true' hamstrings cross both the hip and the knee joint and are, therefore, involved in knee flexion and hip extension. The short head of the biceps femoris crosses only one joint (knee) and thus is not involved in hip extension. With its divergent origin and innervation it is sometimes excluded from the 'hamstring' characterization. The hamstrings play a crucial role in many daily activities such as walking, running, jumping and controlling particular movement in the trunk. In walking, they are most important as an antagonist to the quadriceps in the deceleration of knee extension [6].

2. EXPERIMENTS

First we examine the EMG signals during normal walking. We put the electrodes of the first channel on the rectus femoris and the second channel on the biceps femoris (Fig. 5).

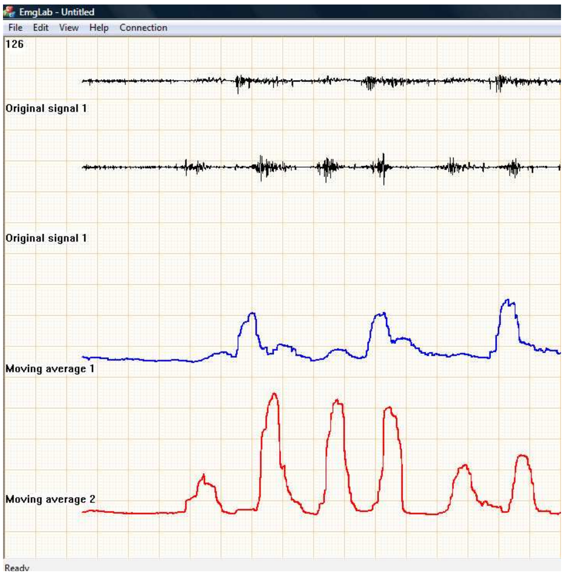

Fig. 5

In the moving average results of the signal we see that first we have a contraction of the biceps femoris then a contraction of the rectus femoris, followed by another contraction of the biceps femoris. The first contraction of the biceps femoris is the lifting of the lower leg of the ground, then the rectus femoris swing the leg forward and then the biceps femoris again takes the load of the bodyweight.

The second experiment is a step climb. Again the electrodes are above rectus femoris and biceps femoris (Fig. 6).

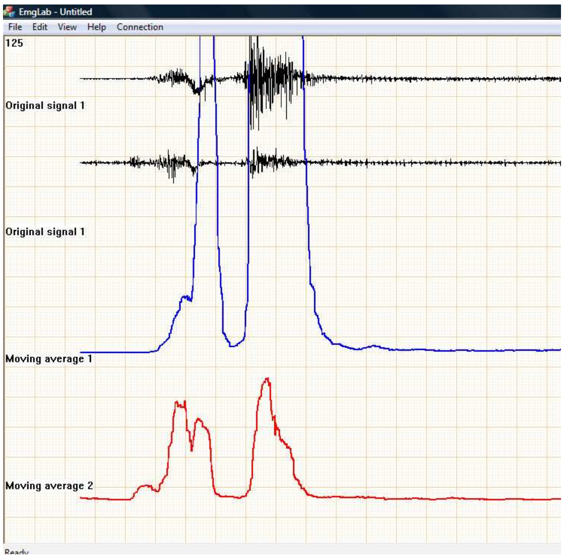

Fig. 6

Here we have a double amplitude peak signal in both muscles which are synchronous. The first impuls is shorter and is associated with the lifting of the leg and planting it on the step, while the second one is the lifting of the body by the leg.

The third experiment is the stepping down motion. Electrodes are again on the rectus femoris and biceps femoris (Fig. 7).

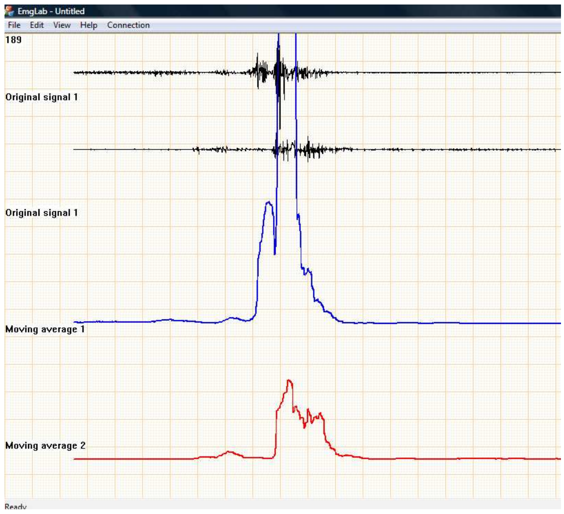

Fig. 7

We have again synchronous signals from both muscles but the signal from rectus femoris is much bigger and is two-phase. The first phase corresponds to the lifting of the leg while the second much bigger phase begins with the planting of the leg on the ground and the beginning of taking the load on it.

3. CONCLUSIONS

We were able to obtain signals from the most common movements – walking, climbing and stepping down. With the Software Emg Lab we were able to record the behaviour of the muscles during this exercises.

From the results obtained we can clearly distinguish all types of movements from just two muscles – rectus femoris and biceps femoris. This can allow us to control the knee joint with a certain degree of accuracy.

Further development may include adding more channels to monitor other channels.

Also a study need to be performed to find a relationship between the movement of the above the knee muscles and the ankle joint.

References

[1] J. Rose and J. G. Gamble, Human Walking, Williams and Wilkins, Baltimore, MD, USA, 2nd ed., 1994.

[2] M. Popovic, A. Goswami, and H. Herr, "Ground Reference Points in Legged Locomotion: Definitions, Biological Trajectories and Control Implications," International Journal of Robotics Research, vol. 24(12), pp. 1013-1032, 2005.

[3] A. Winter, Gait Data, International Society of Biomechanics, Biomechanical Data Resources, http://guardian.curtin.edu.au/org/data

[4] Pan J and Tompkins W. J. "A real-time QRS detection algorithm." IEEE Transaction on Biomedical Engineering, 32:230-236, 1985.

[5] Rangaraj, M. Rangayyan "Biomedical Signal Analysis" Wiley-Interscience Boundless. "Muscles that Cause Movement at the Knee Joint." Boundless Anatomy and Physiology. Boundless, 21 Jul. 2015 https://www.boundless.com/physiology/textbooks/boundless-anatomy-and-physiology-textbook/the-muscular-system-10/muscles-of-the-lower-limb-107/muscles-that-cause-movement-at-the-knee-joint-579-9335/