

# Electromyographic analysis of standing up and sitting down

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## Abstract

*The purpose of the present study is to evaluate the repeatability of the muscular activation strategy used by healthy subjects during standing up and sitting down tasks. Starting point of these experiments is the hypothesis, claiming that the common solution adopted by healthy subjects in a motor task is the result of an optimization process which includes all the anthropometrical, structural and energetic criteria. Consequently, the healthy subjects muscular activation sequence, if repeatable, could be reproduced as a stimulation strategy for paraplegic patients.*

*Results show a very high repeatability of the start and end points of the activation of all the muscles. Interestingly, the availability of contribution of the upper part of the body affects the level of activation but not the timing of activation of all the muscles.*

## 1. INTRODUCTION

Standing up and sitting down are two demanding tasks crucial for autonomy in the daily life. The possibility to switch between sitting on a wheel chair and standing with the support of assistive devices can help patients to prevent osteoporosis and contractures, to limit the occurrence of decubitus ulcers and to help bowel and bladder by improving the position of the internal organs. For these reasons, the chance to perform these two functional movements by FES for paraplegic patients is a very important goal. Standing induced by FES can be achieved with relatively simple systems of surface stimulation providing only a stimulation to the knee extensors. This simple stimulation patterns provokes a high final velocity of the knee which may damage the knee joint. Thus, the development of closed loop control systems able to reduce joint stresses and increase the safety in the movement is required. One of the most difficult and at the same time appealing thing is to include in the control systems the voluntary contribution of the upper body. The patient

driven controllers tried to merge synergetically the natural and artificial action [1].

The aim of this work is to obtain a human like stimulation strategy in order to create a smooth and safe movement. To gain our main objective a electromyographic analysis of the standing up and sitting down movements has been developed. In literature Roebroek et al. [2] analyzed the standing and found out the existence of an efficient co-contraction of the hamstrings and the rectus femoris. In this work we focus on the analysis of all the synergies and the co-contractions in order to propose a human like efficient stimulation strategy aiming at the exploitation of all the muscles.

## 2. METHODS

### 2.1. Experimental setup

The experimental setup was a seesaw with an arms support. This latter was provided with strain gauges in order to detect the arms contribution during the movement (figure 1). The subject wore two Ankle Foot Orthoses to fix the ankle. This is the same setup we intend to use during the stimulation session. The seesaw had the possibility to relieve a percentage of the body weight through a counterweight placed on the supporting device [1], allowing a FES training by decreasing loads.



Figure 1: The experimental setup.

Seven healthy subjects (4 males and 3 females, mean age  $25.7 \pm 1.25$ , weight  $65.7\text{Kg} \pm 13.034$  and height  $172.4\text{cm} \pm 8.96$ ) participated in the experimental sessions.

During the trials the electromyography of 6 muscles of the lower limb was recorded and

knee and hip joint angles were measured by two electrogoniometers as shown in figure 1. All the electromyographic and kinematic data were acquired through an acquisition board with an acquisition rate of 500Hz.

Surface electrodes were placed on the muscles of the right leg following the indications of SENIAM [3]. The recorded muscles were: rectus femoris (RF), medialis and lateral vasti (VM, VL), semitendinous (ST), medialis gastrocnemius (GAM) and gluteus maximus (GLU).

Before the experiments we performed trials of Maximal Voluntary Contraction (MVC) in isometric conditions following [3]. We recorded the MVC of the GLU during a maximal hip extension against a resistance with the hip completely extended. The ST MVC was acquired during a maximal knee flexion against a resistance with a flexion angle of the knee of 90 degrees. This last position was used also to detect the RF, VM and VL MVCs during a maximal knee extension. Finally the GAM MVC was recorded during a maximal plantar extension against an external resistance and with the ankle fixed at 90 degrees.

Each experimental trial consisted of 12 consecutive movements of standing up and sitting down performed with 2 different velocities and with or without the help of the arms for a total of 4 different conditions for each subject. No rest period was given between successive movements.

## 2.2. Data processing

The kinematic data were processed through a 5<sup>th</sup> order low pass Butterworth filter with a cut off frequency of 6 Hz. The EMG signals were firstly high pass filtered through a 5<sup>th</sup> order Butterworth filter (cut off frequency of 10 Hz). Then we rectified the EMG and we performed an Amplitude Processing smoothing the rectified signals with a low pass filter with a time constant of 26.5 ms following [4]. Finally, the activation of the different muscles was extracted using a proper threshold. This threshold was defined as the value in which the processed EMG signals were equal to the mean value of the recorded signal during quiet acquisition plus a margin of 3 standard deviations of the same phase.

## 2.3. Statistical analysis

The parametric three way ANOVA test ( $p < 0.05$ ), was employed to compare the start and end points and the percentage of MVC (independent factors were subjects, trials

velocity and the presence/absence of arms contribution). We performed also a one way intra-subjective ANOVA exploring the significant differences between the presence/absence of arms contribution.

## 3. RESULTS

An example of the EMG levels as a percentage of the MVC of all the recorded muscles during standing and sitting is shown in figure 2.

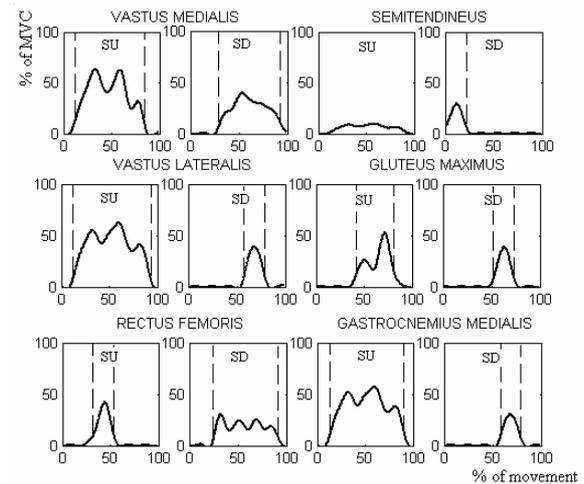


Figure 2: EMG levels of the different muscles during the standing up (SU) and sitting down (SD) movements. Results are expressed as a percentage of MVC. Dashed lines showed the activation windows.

It is clear from figure 2 that the percentage of MVC of all the muscles was always bigger during standing up then during sitting down and this was the effect of the gravity force.

The intra-subjective test for each subject didn't show statistical significant differences among the 4 conditions (fast and slow and with or without arms). The same result was obtained for the inter-subjective ANOVA test. The whole repeatability of the timing of activation led us to the definition of a motor strategy for the standing up and for the sitting down (fig.3).

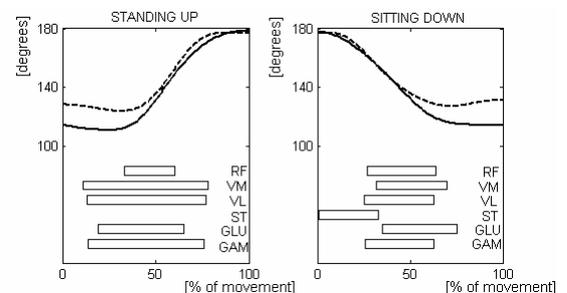


Figure 3: Identified muscular strategy. The knee angle is shown in solid line while the hip angle is in dashed line (180 degrees was the complete extension of the joints). The range of activation of each involved muscle is represented with a bar below the angular trajectories.

During the standing up the very first phase of the movement resulted from a forward rotation of the upper body which provoked a little hip flexion. The muscular activation of such a trunk rotation was obviously not imputable to any leg muscles. Then the beginning of the upward displacement was due to the knee and hip extensors (VM, VL, RF and GLU). The first muscle to be contracted was VM followed by all the others knee and hip extensors. All these contractions were concentric. The contribution of ST was really weak in fact it resulted in the most of the cases under the activation threshold. On the contrary, it is important to underline the eccentric contraction of the GAM which was really important because it slowed down the knee extension avoiding joint risks and smoothing the entire task.

During the stand to sit movement ST started the knee flexion but, just after the very beginning, it stopped because the work is done by the gravity. The sitting down was performed with an eccentric contraction of all the mono-articular knee and hip extensors (VM, VL, RF, GLU). This action was essential to slow down the movement velocity before the impact with the seat. The end of the movement is completed by the backward rotation of the chest.

The three way ANOVA (independent factors were subjects, velocity of the trials and arms contribution) performed on the percentage of MVC of all the muscles showed a statistical significant difference between the subjects for any conditions because of their different muscular trophism. Thus we performed the ANOVA intra-subjective test.

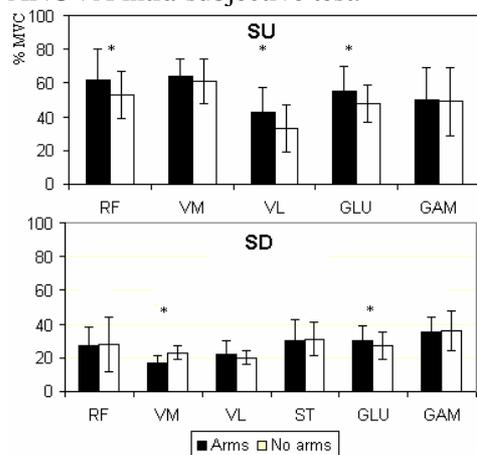


Figure 4: Statistical results on one subject. The asterisks (\*) indicate that ANOVA statistical analysis evidenced significant difference among the presence/absence of the arms support ( $p < 0.05$ ).

We found a significant difference in the percentage of MVC of some muscles only

between the trials performed with or without the arm support (figure 4).

#### 4. DISCUSSION AND CONCLUSIONS

The repeatability of the muscular strategy represented a very neat starting point for the development of a human like stimulation pattern. The idea to recreate a physiological movement comes from the conviction that the Central Nervous System (CNS) produces the movement exploiting concentric or eccentric contractions optimizing the efficiency and the safety of the tasks. In particular during the standing up we would like to avoid the typical risks of FES supported sit to stand tasks, e.g. the excessive velocity at the knee, and the hyperextension of the knee at the end of the movement which could damage the knee joint especially in patients with osteoporotic bone. During the sitting down instead the objective was smoothing the gravitational effects in order to avoid a jerky and violent impact with the seat. In order to reach these objectives a first step would be to stimulate agonists and antagonists in order to slow down and control both the tasks aiming at the production of a smooth movement. In this context the best bench test would be to recreate the physiological behaviour.

The differences between the percentage of MVC of the muscles in presence/absence of the upper body support would be a good reason for the inclusion of this contribution in the controller. In future applications would be possible to measure the force applied to the arms support and consequently tune the stimulation of the legs.

#### References

- [1] Riener R., Ferrarin M., Pavan E. E., *et al.*, Patient-Driven Control of FES-Supported Standing Up and Sitting Down: Experimental Results, *IEEE Trans. Rehab. Eng.*, vol. 8(4), pp. 523-529, 2000.
- [2] Roebroek M E, Doorenbosch C A M, Harlaar J. *et al.*, Biomechanics and muscular activity during sit to stand transfer, *Clin. Biomech.*, vol. 9, pp. 235-244, 1994.
- [3] Freriks LJM, Hermens HJ, European Recommendations for Surface ElectroMyoGraphy, results of the SENIAM project, Roessingh Research and Development BV, (CD-rom), 2000.
- [4] Merletti R., Standards for Reporting EMG data., *J. of Electromyogr. Kinesiol.*, vol 9(1):III-IV, 1999.

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