ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

EMG SIGNAL-ONLY GAIT CYCLE DETECTION ALGORITHM

[1,4] Simone Pasinetti, [1]Matteo Lancini, [2,3]Carolina Da Re, [1]David Vetturi and [1]Alberto Borboni
[1]Department of Mechanical and Industrial Engineering, University of Brescia, Italy
[2]Habilita Zingonia healthcare center, Zingonia di Ciserano (BG), Italy
[3]Department of Surgery and Interdisciplinary Medicine, University of Milano-Bicocca, Italy
[4]Presenting author; email: simone.pasinetti@ing.unibs.it, web: www.unibs.it

SUMMARY

This study present first validation results of a new method for gait cycle detection (identification of start time of each step) during walking, that can substitutes foot switches sensors when their performances degenerate with the use. This method uses directly the acquired EMG muscle signal to find a possible step division, especially in applications where long walks are acquired.

INTRODUCTION

The estimation of the muscular timing is one of the most important method for gait evaluation, especially during rehabilitation sessions. Temporal parameters, like step time and on-off timing, are good indicators in some cases, e.g. for the recruitment strategy study [1].

The analysis results are always referred to a single step while the acquisition is performed on the whole walk, therefore a reliable step-split method is needed. Most of the studies on gait analysis use devices called foot-switches for the gait cycle detection. They are pressure sensors that can give two constant tension values: a low value when the foot doesn't touches the floor and an high value when the foot-floor contact happens. Notwithstanding their popularity, these sensors could fail in some applications. One problem is their life-cycle: these sensors use a contact to measure the step phases and in studies with long walk protocols a signal deterioration could arise. A further problem could be the set-up time. In fact, for a good division an high positioning accuracy is needed. Wrong positioning can generate wrong division, generating longer or shorter step with respect the real one. For the sensors that use an innersole [2] an high calibration could reduce this problem but it increases the cost of the whole system. A lot of these systems are wireless but they need a battery for the energy supply. Wired sensors [3] could hinder the patient movement since in these studies other devices are also used (e.g. EMG recorder, oxygen consumption measure, etc.).

In this paper a new method for the step division is proposed. This method use directly the signal generated from the muscles and acquired using surface electrodes and a EMG recorder. Using directly the information that comes from the EMG recorder the set up time decrease and the whole system is simpler due to the presence of less devices.

METHODS

The main idea behind this method is that the number of the steps in a walk is directly linked to the number of activations of the muscles involved. Then, if we study a muscle with a single-phase activation we can directly know how many steps the patient have taken during an acquired walk. Furthermore, knowing the activation moments of that muscle, a possible gait division could be computed. The steps found in this way differ from the steps found with a classical split procedure using foot-switches (that goes from one heel contact to the next of the same side) by a constant delay time. This is a procedure only for gait cycle detection, not for gait phases identification that can be computed using other techniques.

For this work the muscle chosen is the soleus that is one of the muscles that control forward movement of the tibia on the foot, participating in the forward propulsion of the body [4]. Figure 1 shows a typical timing of that muscle during a classical gait cycle.

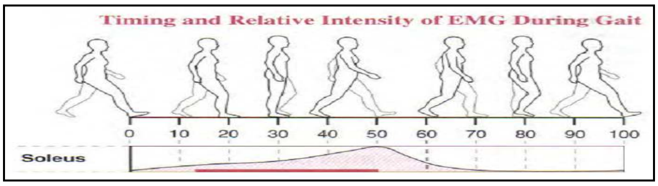

Figure 1: Typical activation and timing of the soleus during a classical gait cycle.

The proposed method involves digital filtering phases to simplify step splitting. First of all the gait signal is band-pass filtered (Butterworth filter) to maintain only frequency components directly associated to a real contraction, and to reduce electrical noise and motion artifacts that are in the signal. The cut off frequencies are 30 Hz and 150 Hz [1]. On the filtered signal the root mean square (RMS) value is computed: windows of *w* width are placed on the signal each *dt* seconds (sampling time), and the RMS value is computed on those portions of signal. Then using a threshold on the computed signal, the rising edges can be found. The threshold must be chosen properly to allow the correct steps division: it must intercepts all the peaks of the RMS signal to find all the steps included into the acquired gait. A good value of the threshold is between the 10th and the 40th percentile of the whole gait signal. For this work the 30th percentile was chosen. Each rising edge represent an indicator of the step start time and can be used for gait cycle identification.

RESULTS AND DISCUSSION

The validation is done comparing some temporal gait parameters found with the proposed algorithm and the same parameters found using foot-switch technique. The algorithm validation has been performed on 11 healthy subjects. Each subject did three 20 minutes walks, at 3.2 km/h velocity, on two different supports: the first and the third one on a treadmill and the second one on a Lokomat (gait orthosis for automated locomotion). From this three long walks, six short 30 seconds walks are extracted: after 1 minute from the first one (walk 0), after one (walk 1), 10 (walk 2) and 20 minutes (walk 3) for the second one and after 10 (walk 4) and 20 minutes (walk 5) for the third one. For each short walk only the steps with a good footswitch signal are considered for the comparison (982 total steps). For each step the extracted parameters are:

- t_{step} (step time) in seconds: step duration;
- $t_{step,rel}=t_{step}/(\bar{t}_{step,walk0})$ (relative step time): step duration respect to the average step time of walk 0 for each subject;
- *Span* (activation span): duration of muscle activation respect to the step cycle;
- t_{on} (activation instant):% respect to the step cycle;
- t_{off} (deactivation instant): % respect to the step cycle.

Figure 2 and figure 3 show the results for all the analyzed steps. Figure 2 shows a similar distribution for the step time and the span, both for the foot-switch technique and using the information from the soleus. Histograms of relative step time have a different distribution: the soleus technique causes a wider dispersion that could be due to the presence of activation variability that soleus has and that is not considered by foot-switch split method.

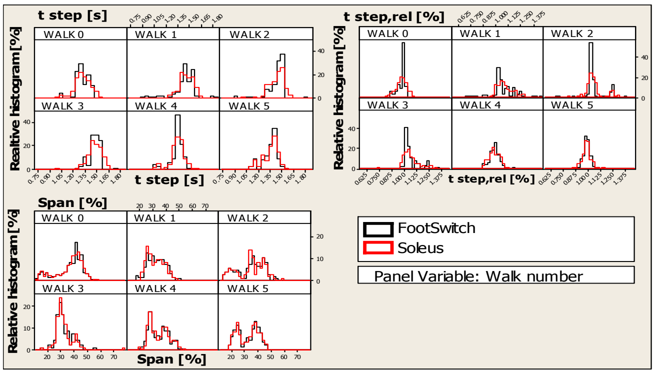

Figure 2: Histogram comparison of step time, relative step time and activation span for each walk using the two techniques (black line: foot-switches; red line: soleus).

Figure 3 clearly shows that both activation and deactivation time have the same trend in all the walks considered for the two splitting methods. The standard deviation is smaller for the proposed method being soleus both the muscle under consideration and the one used to trigger the step phase. Clearly the two parameters have different averages because in the soleus method, delay time between the heel-on and the muscle activation is not considered and the step cycle is time-shifted with respect to the classical definition. This causes a decrease of activation and deactivation instants with respect to literature values. Single steps analysis give similar results: parameters extract with proposed algorithm are compatible with parameters found with foot-switches.

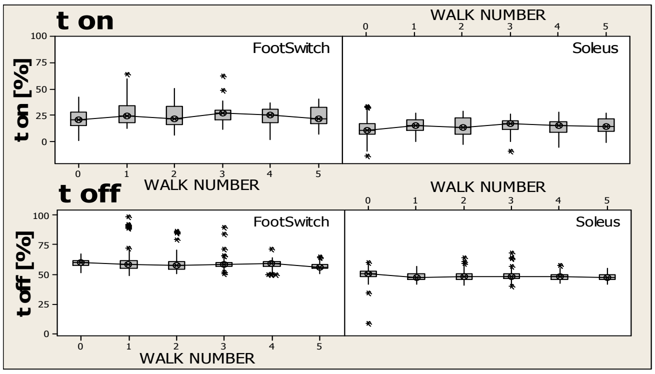

Figure 3: Comparison of activation and deactivation instants of the soleus for each gait, using the two techniques.

CONCLUSIONS

The proposed method gives good results, compatibles to the standard method results. Proposed method detects correctly the gait cycle allowing a gait evaluation without foot-switches. Found gait cycle is different from the classical one because it goes from one muscle activation to the next one and a manual shifting correction is required. This two methods could be integrated to have redundant information about the gait cycle and to improve the accuracy of the division. Using an integrated procedure the step cycle can be easily aligned to the standard one automatically, having parameters that could be directly comparable with literature.

Even though this method has been proven to work well on healthy people, using this muscle, also people with low level walk pathologies can be studied because in this kind of pathologies the single-phase property of the muscle is usually maintained [5]. In any case, this problem can be fixed taking a muscle that maintain a single-phase activation also in pathological patients.

A deeper examination is in progress, to perform a further validation with variable velocity and on pathological patients.

REFERENCES

1. Merlo A., et al., *The open rehabilitation journal*. **3**:98-109, 2010.
2. Hausdorff J. M., et al., *J. Biomechanics*. **28** (No. 3): 347-351, 1995
3. Beauchet O., et al., *Gait and Posture*. **27**: 156-159, 2008.
4. Newmann D. A., *Kinesiology of the musculoskeletal system*, Elsevier-Mosby
5. Perry J., *Gait analysis – Normal and pathological function*, Slack Incorporated.
6. Gazendam M. G. J., et al., *Gait and Posture*. **25**: 604-614, 2007.
7. Hof A. L., et al., *Gait and Posture*. **21**: 171-177, 2005.