A STUDY OF EMG SIGNALS FROM LIMBS WITH CONGENITAL ABSENCE AND ACQUIRED LOSSES

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INTRODUCTION
The basic assumption made by the designers of EMG amplifier systems is that the substantial difference between different person's detected EMG signals is the energy generated, but the spectral content is sufficiently similar to be ignored. Anecdotally, there is little or no expectation that there is any structural difference between the muscles of persons with congenital absence and those with an amputation, although newer evidence suggests this is untrue [1]. This approximation works well for simple amplifier/detector systems that were common a decade past [2], but with the increasing availability of compact on-line processing devices and the increase in differing EMG processing schemes this approximation is likely to prove unreliable [3].

This study was made with persons who attended the Oxford Limb Fitting Centre at the Nuffield Orthopaedic Centre, Hospital in Oxford UK, from 1989 to 2001 as part of a program looking at novel means of processing and the analysis of EMGs [4,5]. It sought to understand the variability of the results as they were derived from the techniques applied (Fuzzy logic, Neural Networks and Wavelet transforms). While undertaking the study the new information from the structural studies in Texas [1], showed that it was a worthwhile exercise, and one likely to produce unexpected results.

METHOD
Electromyograms from five individuals with congenital absence (CL) of their forearms were compared with those from three persons with acquired losses (AL) and eight without any losses (NL), an additional subject with a loss above the elbow was recorded. The subjects with a limb absence were drawn from the user population of the centre and had a wide range of prosthesis experience, from passive through body powered to active myo-electric users. The signals were detected using a custom-made Delsys Bagnoli-2 system and the conventional electrodes. This system was commissioned especially for the experiment after initial experiments with a Motion Analysis system and a custom-made in-house system showed a need for a wider bandwidth than was usually available. The custom systems bandwidth extended from 11Hz to 3.4kHz. The data was then collected on a PC via a standard data capture techniques.

Each subject was asked to contract a muscle on the forearm. If they used a myoelectric prosthesis, then their control muscles were chosen. Otherwise the muscle they had best control with was used. For comparison, the contra-lateral of the muscle was also recorded.

The signals were processed and analysed using skew and kurtosis of the frequency analysis using Fourier and Hilbert transform based techniques [4,5]. The latter is a technique that allows a greater resolution of the frequencies of the signals than
RESULTS

Across all measures there was a detectable difference between the CL group and the AL group, but little difference between the AL subjects and the NL cohort. For example, the measured skew for the frequency analysis of the CLs signals was (51 +/- 20) this was about double the value of the NLs (27 +/- 1), but the skew for the AL group was in the same area (29 +/- 10). This analysis used the Marginal Hilbert spectra rather than the Fourier based Power Spectral Density function, which is less sensitive, but achieves a similar separation, because of this three CLs and one NL had to be excluded.

A t-test between the three groups showed a strong separation, with a value of 83% likelihood that the Normal and Acquired populations are the same, while the chances of the CLs and NLs being in the same population was 3% and that the two limb absent groups being the same being as low as 6%.

Figure 1  The skew of the Marginal Hilbert Spectra of the three groups; (CLD) Congenital absence, (NLD) No loss group, (ALD) Acquired Loss.

The Ultra-sound scans of the CL muscle agreed with the more extensive MRI study by Farry et al. [1], that the fibres were less ordered and the muscle had a more
amorphous structure.

Figure 2 Fourier transform based Power Density Spectra for the two groups: Dotted lines are CLDs and solid lines are NLD subjects.

DISCUSSION
From the data, it is clear that there are both structural and electrical differences between muscles in persons with a congenital below elbow loss and those who lost their limb later. There are a number of factors that need to be considered before a possible explanation can be considered.

The differences are likely to be developmental and not a matter of usage, since some of the subjects are described by their prosthetists as heavy users of their myoelectric hands and this did not lead to any correlation between the groups. There was no particular variation based on gender, side or age.

Fatigue can be discounted as another study on the effect of measured frequencies using the MHS showed a lowering of the frequencies as evidenced by the skew measures[3]. If this is coupled with the knowledge that the myo-arm users would be likely to have a greater endurance than the non-users, it would seem unlikely that the changes were based on fatigue.
There were little difference between measured isometric and isotonic contractions in conventional muscle, thus it seems unlikely that the factors relating to the tethering of the amputated muscle would be the explanation.

The observation of a difference in the structures of the muscle suggests the fibres are not in a parallel arrangement, this difference could be due to the fact that fibres in normal muscle are pulled by the joint and will tend to develop in one direction, growing to respond to the stimulus. What direct effect this might have on the signal can only be speculated at this point.

**IMPLICATIONS**

Irrespective of the causes, the observation has some implications for myo-processors. That all users have been able to employ the narrower bandwidth in everyday use is likely to be because although the CL users have a wider bandwidth they still produce energy at the lower frequencies, although it might explain the instances when the observed raw signal is looks sufficient, but the output of an amplifier/processor needs more gain than might be expected.

That the bandwidth for some users is wider need not necessarily mean the amplifiers must have a wider bandwidth. Allowing the higher frequencies may make the system more prone to other sorts of interference, thus practically speaking it might be better to continue as before, simply being aware of the differences.

However in recent years there have been a number of proposals for newer and more sophisticated myo-processors based on the underlying structure of the signals, including learning systems. Reported variations in their performance might be explained by the fact that no reference was made to the cause of the limb absence.

**CONCLUSION**

It is not safe to assume that all users of a myoelectric system are the same. Advanced controllers need to have a wider bandwidth if they are to be as useful for all possible users.

Of course the simplistic response is to simply turn up the amplifier gain.

**REFERENCES**