Understanding the Effect of Clothing Pattern On E-Textile Electromyography (EMG) Electrode Performance

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Introduction. Electromyography (EMG) is a diagnostic recording system routinely used in clinical application to measure electrical activity of striped muscles as voltage and get information about the health condition of neuron groups that stimulate these muscles. Surface EMG, which can also be applied wirelessly, is widely used to study the dynamic muscle activity where the signals from muscles are registered noninvasively from the skin surface by electrodes to evaluate sports performance without interfering with movements. When compared with the conventional, single use, hydrogel Ag/AgCl electrodes that require skin preparation, electronic textile (e-textile) electrodes present multiple advantages including the possibility of being integrated into clothing for continuous muscle activity tracking.

Research shows that embroidery method provides repeatable and highly accurate results in manufacturing e-textile EMG electrodes (Oliveira, et al, 2014; Catarina, et al, 2012). When e-textile EMG electrodes are integrated into clothing, fit of the clothing on the body and therefore cut and pattern become important factors effecting the signal quality (Cho et al., 2011). Fit directly affects the contact and pressure between the skin and e-textile electrode and therefore signal noise and electrical resistivity of e-textile EMG electrodes. This research analyzes the effect of pattern in clothing design on embroidered EMG electrodes' performance during arm movement in comparison to the conventional hydrogel Ag/AgCl electrodes.

Materials and Methods. T-Shirts are prototyped in two different pattern variations using a two-way stretch, polyester jersey knit fabric. Set-in sleeve and raglan sleeve patterns are selected as they are widely used in athletic wear and as they create different fit conditions around the shoulder and arm. Two T-shirt patterns with set-in sleeve and raglan sleeve are custom drafted for a male participant whose measurements were retrieved using a Size Stream 3D body scanner. T-shirt patterns with set-in sleeve and raglan sleeve are then manually drafted based on the extension percentage of the knit fabric in course direction (138.3%) (BS EN 14704-2005 standard).

E-textile EMG electrodes are embroidered on the right sleeve pattern of each T-shirt prototype using polyamide silver-plated Madeira HC40 ($<100\ \Omega$/m) thread and satin embroidery stitch with ZSK Sprint embroidery machine. Two embroidered electrodes with 20mm diameter are located 40 mm apart from each other on the sleeve pattern to correspond to the location of the Biceps Brachii muscle of the arm. Embroidered electrodes' as well as conventional EMG electrode's resistance and signal to noise ratio (SNRdB) are measured.

Three sets of EMG measurements are taken from the participant under three conditions (Bare skin with conventional hydrogel electrode, Raglan sleeve T-shirt with embroidered electrode, Set-in sleeve T-shirt with embroidered electrode) in a random order. EMG measurements are retrieved using a wireless Delsys snap EMG sensor as the participant engaged in a 2.5 kg dumbbell biceps curl movement repeated for 10 times. Collected EMG signals under three different conditions are analyzed according to the EMG signal forms and SNRdB values to evaluate effect of sleeve pattern on embroidered EMG electrode performance in comparison to conventional hydrogel electrodes applied to the bare skin. In addition, power spectral density (PSD), a tool for analysing EMG data in frequency domain characteristics, is used to compare the EMG signal further.

Results and Discussion. Results showed significant difference between the embroidered electrode and the conventional electrode with lower electrical resistance and higher SNRdB value for the e-textile electrode (Table 1).

Table 1. Electrical characterization of embroidered and conventional EMG electrodes.

	Mean R (Ohm)	SNR (dB)
Embroidered Electrode (Satin Stitch)	0.087±0.005	70.83
Conventional Electrode	649.33±145.14	60.63

Embroidered e-textile electrodes with satin embroidery stitch on both sleeve patterns showed better SNRdB values compared to the conventional Ag/AgCl electrodes based on the measurements retrieved during movement (Table 2). The EMG measurements retrieved with the raglan sleeve T-shirt showed the highest SNRdB value and therefore superior signal quality compared to set-in sleeve pattern variation. Based on these findings it is possible to discuss that the raglan sleeve pattern T-Shirt which does not have a seam directly on the shoulder joint, gets less affected from the arm movement and therefore offers continuous contact between the e-textile electrode surface and the skin. On the other hand, the seam on the shoulder joint for the set-in sleeve T-Shirt does not stretch and causes contact loss between the e-textile electrode surface and the skin during movement.

The maximum frequency in PSD is used to measure muscle fatigue after an activity. It is expected to have the EMG signal frequency within the range of 10Hz to 500 Hz. Results indicated that measurements taken from both the set-in sleeve T-Shirt and the raglan sleeve T-shirt are within this ideal range.

Table 2. Electrical characterization of embroidered and conventional EMG electrodes according to the sleeve pattern.

	SNR (dB)	Maximum frequency in PSD
Set-in sleeve T-shirt	17.01±2.38	16.67±1.53
Raglan sleeve T-shirt	26.21±2.94	27.33±12.66
Bare Skin with Conventional Electrode	12.81±2.51	46.33±6.51

Conclusion. This study investigated the effect clothing pattern in EMG applications using e-textile electrodes integrated onto the sleeves of T-shirts with set-in and raglan sleeve. Raglan sleeve pattern, widely used in athletic wear to provide extra ease for the movement of shoulder joint, showed superior performance and therefore indicated the pattern of a garment could have significant effect on EMG signal quality in the design of smart clothing.

References

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