Innovative methods for addressing the
perplexing issue of EKG artifact

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A common observation when working with EMG amplitude signals is a rhythmic spike in activity, typically occurring about once each second. While not observed with all placements, this rhythmic activity is prevalent with wider placements that are close to the chest. These spikes in the amplitude signals are caused by the spread of the electrical activity of the heart during ventricular contractions. Cardiac muscle generates a powerful electrical field that spreads throughout the body. The electrical signal of the heart is called the electrocardiogram, or EKG or ECG. The EKG signal can provide a great deal of information about the function of the heart and is routinely studied by cardiologists using a 12 lead setup.

For those of us using surface EMG feedback for relaxation or neuromuscular retraining, the EKG signal is a source of physiological noise that can interfere with training. Frequent spikes of activity make line graphs and bar graphs difficult to interpret and can make feedback choppy and unusable. The ideal way to remove the EKG noise would be to simultaneously record the EKG signal and subtract that waveform from our EMG signal. This is difficult to implement from a technical perspective and the commercial biofeedback systems do not provide this function.

Two approaches for dealing with EKG noise are available in most biofeedback systems. One involves smoothing the signal, by averaging the signal from the current epoch with the signal from prior epochs. The amount of smoothing can be varied by changing the number of prior epochs that are averaged. Many systems use an epoch duration of 1/32 of a second for EMG amplitude and permit a range of averaging from two epochs through 64 epochs. Typically, the minimal amounts of smoothing with 16 or fewer epochs still yield a fairly choppy signal. With near maximal smoothing, the amplitude signals can be smoother, but they will also be much more sluggish in responding to true changes in EMG activity.

The second approach to dealing with EKG contamination or noise is to change the bandpass settings for the digital filters. EMG activity occurs over a fairly wide range of activity ranging from about 10 Hz to more than 500 Hz. Much of the activity is between 20-200 Hz and the contributions to total energy from below 20 Hz and above 200 Hz tend to be quite modest. The older biofeedback systems often provided a switch to change bandpass settings between two options. The wide setting was typically from 20-1000 Hz while the narrow setting was from 100 to 200 Hz. All of the currently available systems provide the capability of setting the low and high cutoff settings independently to a specific value in Hertz.

A very informative way of looking at frequency effects on EMG activity is to examine the power spectrum of the EMG signal using a Fourier analysis. The software in our systems includes the capacity to calculate a fast Fourier transformation, or FFT, that can provide a graphical representation of signal power over a range of frequencies. When EKG spikes are

present in the amplitude displays, the power spectrum reveals rhythmic waves of activity in the lower frequency ranges. There is significant variability across subjects and placements, but for the most part the EKG signal is present in the 10-60 Hz range. I have not determined why an interbeat interval typically ranging from more than .5 second to less than 1.5 seconds generates activity in the 10-60 Hz range, but it is probably related to the rapid deflections in EKG activity during the QRS complex.

Since the EKG activity is confined to the lower frequency ranges we can reduce or eliminate the spikes in EMG amplitude activity by raising the low cutoff frequency. I have found that changing the low cutoff from 20 Hz to 50 Hz can greatly reduce the EKG spikes. If the amplitude signal continues to show significant EKG spikes with a low cutoff of 50 Hz, it can be raised to 70 or even 80 Hz. I have yet to see a noticeable EKG spike when recording EMG activity with a low cutoff of 80 Hz.

Since a low cutoff of 70 or 80 Hz will eliminate all EKG noise, why not routinely use a setting of 80 Hz to 500 Hz? The problem is that, as I have already mentioned, there is considerable EMG activity in the range of 20 to 80 Hz. A low cutoff of 80 Hz greatly attenuates that activity and our amplitude signals will be much lower. By eliminating the EKG contribution to the total signal we are also sacrificing a significant amount of the activity we are trying to measure. The preferred approach is to use the lowest possible value for the low cutoff that still provides a reasonably smooth amplitude signal.

It is possible to adjust the low cutoff for each client and even for each session. However, if we use different values, then the overall amplitudes will change, making it very difficult to track progress. The recommendation is to use a fixed cutoff routinely, modifying it only in extreme cases in which the signal remains too choppy to be useful.

Many clinicians using EMG training for relaxation are unfamiliar with the impact of filter settings on the obtained signal. I have created a set of screens that allow students, therapists and researchers to see the effects of different bandpass settings on EMG activity. Some of the screens include the filtered signal, the power spectra and a composite line graph of amplitude signals at three different bandpass settings. Other screens provide line graphs of EMG amplitude and these can display comparisons of the signals at different bandpass settings. When displaying the line graph for the wide bandpass setting, you can also study the impact of smoothing by moving the cursor to the line graph and changing the smoothing setting by hitting the "S" key or shift and "S". I have included screens for signals from the A input or C input. The screens can be used to playback stored sessions or while recording new ones.

I hope that these screens will be useful to individuals wanting to learn more about EMG recording techniques. This is a complex field, but one with great potential. Please feel free to contact me (Rrosent710@aol.com) with any comments or suggestions. To install the screens, move the entire folder called EMG filter demonstrations into the screens directory in BioTrace and the channel set called 4XEMG set into the channels folder. The screens will not function properly without the supplied channel set. The screens can be loaded manually or displayed on a secondary display from a selection screen.
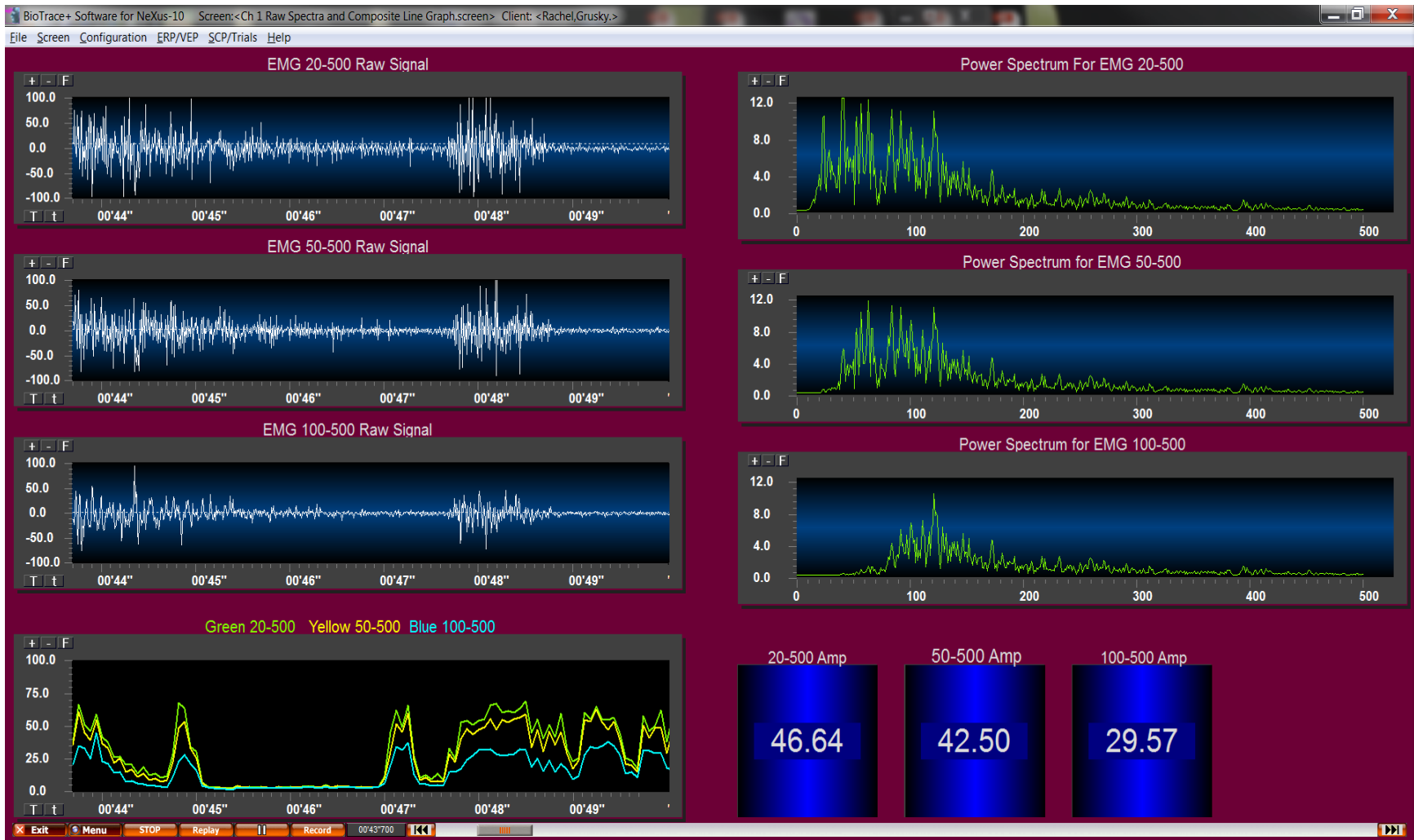
EMG Filter Demonstration Screen. This screen displays the filtered output, the power spectra, line graphs and numerical objects for an EMG signal filtered at 20-500. 50-500 and 100-500 Hz. The recording is from the wrist extensors and shows no EKG contribution.
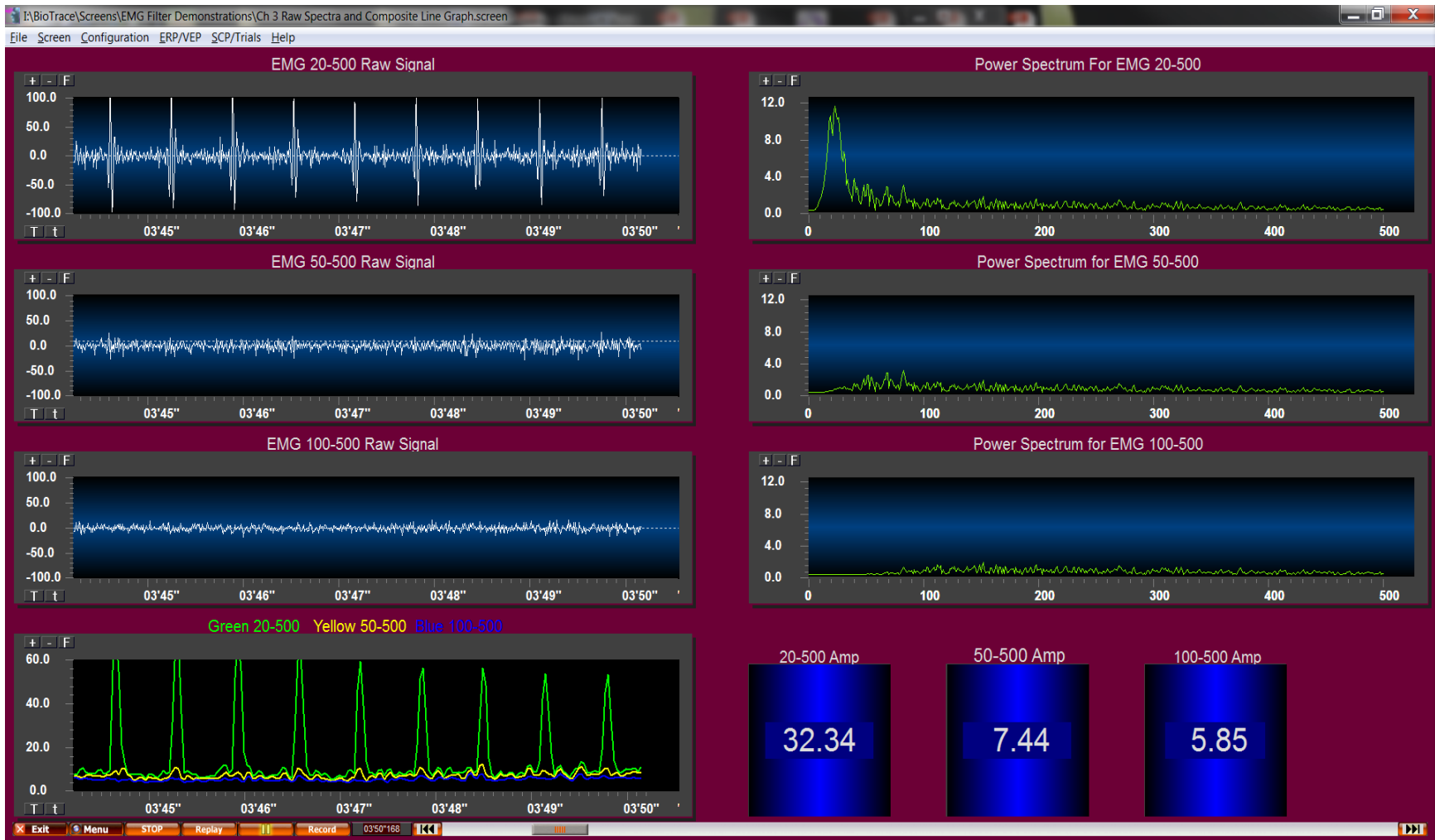
Same as above but with placements (modified frontal to posterior neck) showing significant EKG artifacts.
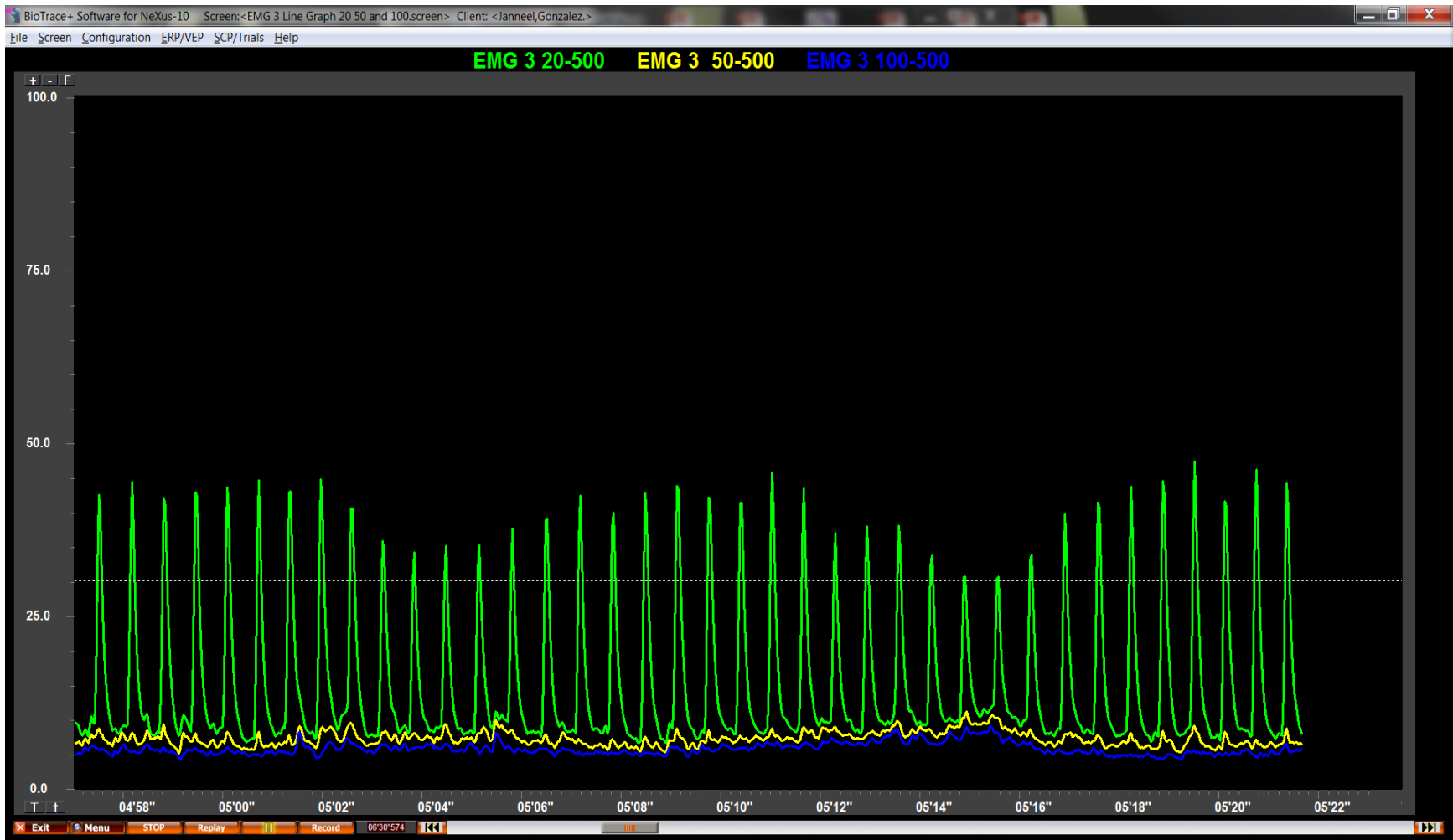
Line graphs of EMG amplitudes with different filter settings and significant EKG artifacts. (Yes, this client does have a high heart rate).
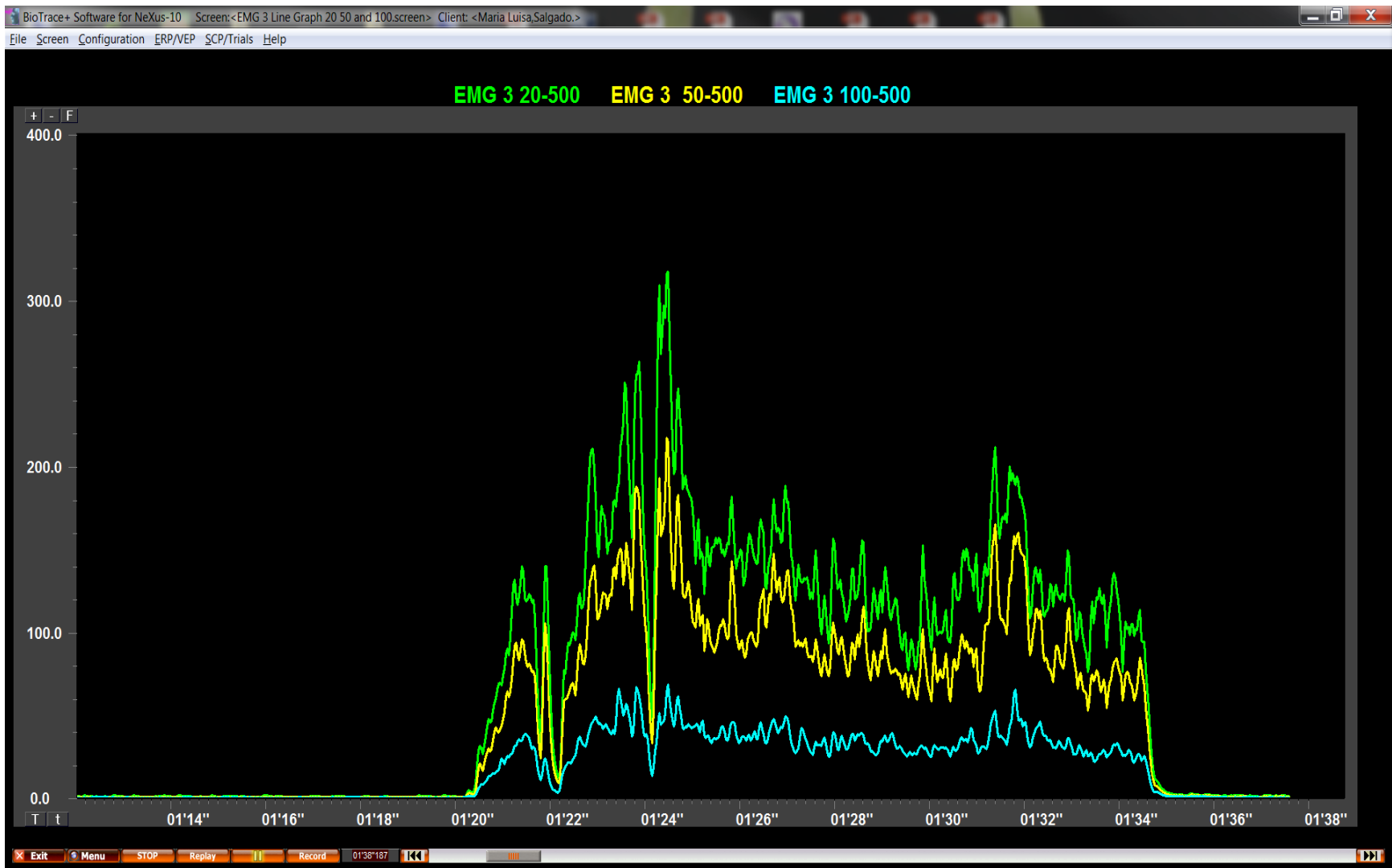
Line graphs at three different filter settings of EMG amplitude from the anterior tibialis muscle during sustained ankle dorsiflexion. This is a site in which EKG artifacts are not typically seen and shows the dramatic impact of raising the low bandpass cutoff on overall amplitude levels.