The assessment of vibromyographical signals in the time and frequency domains during a fatigue protocol

B.Humphries* & G. Warman
The School of Health and Human Performance, Central Queensland University.

INTRODUCTION

Vibromyographic (VMG) signals are detected from accelerometers located on the skin surface over a contracting muscle and represent the oscillations of the internal musculature in the form of mechanical activity (Barry et al., 1995; Herzog et al., 1994). Such skeletal muscle sounds and vibrations have been known to occur for more than three centuries. However, not until the last few decades with the improvement in technology has the application and analysis of vibratory signals been utilised to examine these effects on the contractile ability of human muscle.

Studies applying vibration to muscles have been shown to improve muscular strength and power development (Issurin and Tenenbaum, 1999), improve movement of neuromuscular deficient patients (Hagbarth and Eklund, 1966), improve kinaesthetic awareness (Burke et al., 1996), prevent bone loss (Flieger et al., 1998) and provide insights into the effects of fatigue (Herzog et al., 1994).

Research has demonstrated an accompanying shift to the left or decrease in the VMG signal of the median frequencies using fast Fourier transforms (FFT) as the muscle undergoes progressive muscular fatigue. Studies utilising electromyography (EMG) (Bigland-Ritchie, et al., 1981) and acoustic myography (AMG) (Barry et al., 1995) signals have also shown a similar decrease in high frequency content at the onset and progression of muscular fatigue (Herzog et al., 1994). In a study by Herzog and others (1994) the median frequency of the rectus femoris muscle demonstrated a significant reduction of 50% after an isometric fatiguing protocol.

Further work involving vibration have found variation in the fundamental frequencies of the VMG signal as a result of the intensity of muscle vibrations with respect to the contraction level (Zhang et al., 1992). Studies have also shown the muscles with a large portion of slow twitch (type I) fibres generate signals with increased lower frequencies than muscles expressing higher fast twitch (type II) fibres (Mealing et al., 1996).

The effect of vibration stimulation on muscular strength is an emerging field of research with very little comprehensive work conducted at this stage. At present there appears to be even less available data on the effects of vibration stimulation and its influence on muscular fatigue. The purpose of this study is to investigate the behaviour of the fundamental frequencies produced by the rectus femoris muscle when performing an isometric fatiguing protocol under conditions of no vibration and vibration.

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METHODS

Subjects: Sixteen participants were recruited from the Central Queensland University and local communities. Each participant was advised on the procedures and requirements then completed an informed consent document, and was asked to complete a pre-activity readiness questionnaire to screen for any neuromuscular disorders that may have excluded them from the study. Central Queensland University Human Ethics Committee gave approval for the experimentation.

Vibratory Stimulation: A four kilowatt, three phase electrical induction motor (TECO Co. Ltd., Taiwan) running at 2870rpm (50 Hz) was directly coupled to a two cylinder air conditioning compressor with exposed piston faces driven by an offset cam (Motorcraft, Australia). A velcro strap was wrapped firmly around the participant's upper thigh and clear of the EMG electrodes and accelerometer collecting from rectus femoris (RF). A connecting velcro strap was anchored at one end to the face of the piston, while the other was attached to the participant's thigh to transfer vibration to the leg. The output of a triaxial was recorded by an AMLAB computer (Associative Measurement, Sydney, Australia) sampling at 1000 Hz. The data was'analysed via FFT collecting 1024 data points in the last second of a five second period. Results of this collection confirmed that the system was delivering 50.42 ± 1.16 Hz at $13.24 \pm 0.18 ms^{-2}$.

Mechanical Force Measurements: Peak isometric force (N) was recorded via a load cell (Scale Components, Brisbane, Australia) anchored to the laboratory wall and attached to a cuff designed to slide onto the lower leg of the participant. Data collection was achieved via an AMLAB computer sampling at 1000 Hz for a period of five seconds. Subsequent analysis involved establishing the peak values of the full five second contraction.

Electromyographic (EMG) Data Collection and Analysis: The EMG signals were collected from RF muscle via silver/silver chloride (Ag/Ag Cl) surface electrodes (10mm x 30mm) (3M red dot, 3M Health Care, St.Paul, USA) with an interelectrode distance of 5mm. Electrodes for RF were positioned on the lateral side of the pennation, 190mm proximal to the tip of the patella along the mid-line of the thigh. Electrodes were positioned as to perpendicularly dissect the fibres. A reference electrode was placed on the patella of the participant's involved limb. Preparation of the skin involved removal of any hair and excess dead skin cells, and subsequent cleaning with an alcohol swab. Data collection was achieved via an AMLAB computer sampling at 1000 Hz. Synchronisation of EMG with the VMG and force data collection was achieved via a software trigger set at 30 N force for the isometric contractions. The raw signal for each contraction type was initially analysed using root mean square (RMS) calculations. Peak EMG_{RMS} signals were normalized and expressed as a ratio of a resting value.

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Vibromyographic (VMG) Data Collection and Analysis: The VMG signal was collected from RF via a triaxial accelerometer (Applied Measurement, Victoria, Australia), positioned medially and affixed to the skin by doubled-sided tape and held there with sports tape. The raw VMG signal was analysed using RMS calculations. Peak VMG signals were identified using the same technique as used for the force data.

Lactate Collection and Analysis: Blood lactate levels were recorded for all subjects pre and immediate post all testing conditions. Blood lactates were analysed using an Accusport lactate analyzer (Accusport, USA).

Experimental Protocol: Participants completed a familiarisation session seven days prior to the collection of all data to ensure that they were comfortable with the testing procedures. All participants performed a standardised warm-up incorporating five minutes on a cycle ergometer (Monark, Varberg, Sweden) at 60 W, followed by two minutes of static stretching of the quadriceps and hamstring muscle groups of the dominant leg (as determined by kicking preference). All participants performed two testing protocols separated by a two-hour rest period. Participants randomly performed either: an isometric fatiguing protocol under no vibration or an isometric fatiguing protocol under vibration. The fatiguing protocol involved the performance of a series of maximal isometric contractions separated by a 5 second rest phase, continuing this cycle for a minute. Participants were positioned in a dynamometer chair with straps anchored across the chest and waist. A cuff anchored to the laboratory wall was placed on the lower leg of the participant and adjusted such that the knee, whist performing knee extension, was held in a position of 120∞ flexion.

Statistical Analysis: Mean ± standard deviation data was presented for all subject characteristics. Statistical analysis involved paired t-tests to determine the issue of fatigue for both protocols by comparing pre and post within condition measures. Statistical analysis also involved a one-way analysis of variance (ANOVA) comparing post vibratory data for peak isometric force, peak normalised EMG_{RMS}, lactate measures and peak frequencies for each condition. Statistical significance was accepted at or below 0.05

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RESULTS

The mean age, body mass and height of participants was 22 ± 4.4 years, 73.2 ± 11.7 kg and 173.1 ± 9.7 cms, respectively. A paired t-test revealed significant ($p < 0.05$) within condition differences between pre and post measures for peak isometric force, peak normalised EMG_{RMS} and lactate measures for the two fatiguing protocols. A one-way ANOVA revealed no significant differences between the post values for peak isometric force (see Figure 1), peak normalised EMG_{RMS} (84.74% Vs 88.1%) or lactate measures (see Figure 2) between the two fatiguing protocol conditions. An ANOVA revealed significant ($p < 0.05$) differences between the peak fundamental frequencies of the FFT at the completion of the isometric fatiguing protocols between the non-vibrated (9.8 ± 3.5 Hz) and vibrated conditions (27.1 ± 12.2 Hz).

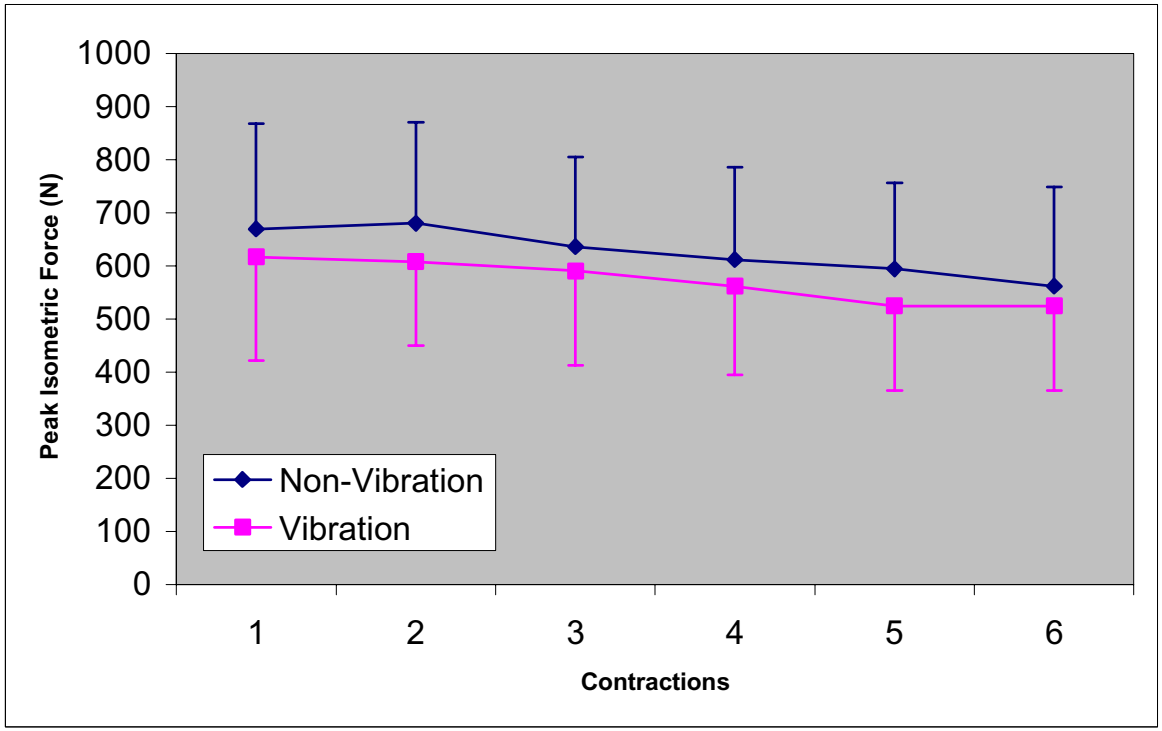

Figure 1. Peak isometric force values performed every alternate five second time interval during the minute long fatiguing protocol for the non-vibration and vibration conditions.

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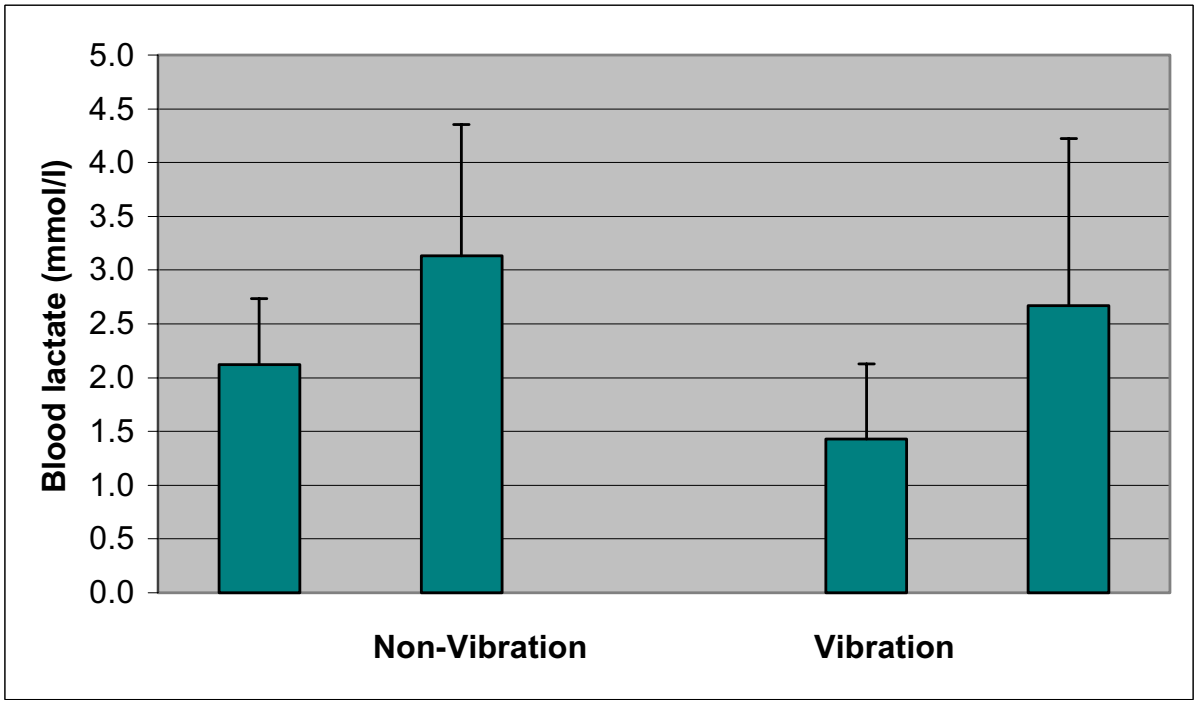

Figure 2. Pre and post lactate measures for the non-vibration and vibration treatments after the minute long fatiguing protocols.

DISCUSSION

The present results indicate significant changes to peak isometric force, peak normalised EMG_{RMS} values and lactate measures as a result of the isometric fatiguing protocol. A comparison of data between the post values for both fatiguing conditions indicated no significant differences between peak isometric force, peak normalised EMG_{RMS} values and lactate measures. Interestingly, there was a significant reduction in the peak frequencies of the VMG signal of the rectus femoris after the non-vibration condition, indicating a state of fatigue of the large fast fatiguing motor units. These results are in agreement with the previous findings of muscular fatigue obtained using VMG signals (Herzog et al., 1994).

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What was most interesting was the shift of the peak frequency of the VMG signal of the rectus femoris after the vibration condition, indicating a state of less fatigue. This is contrary to the shift of a fatigued muscle. These results would indicate firstly, the benefits of vibration treatments to combat the effects of fatigue and secondly, the use of VMG peak frequency analysis derived from FFT's to expand the potential for studying mechanisms of muscular fatigue. '

REFERENCES:

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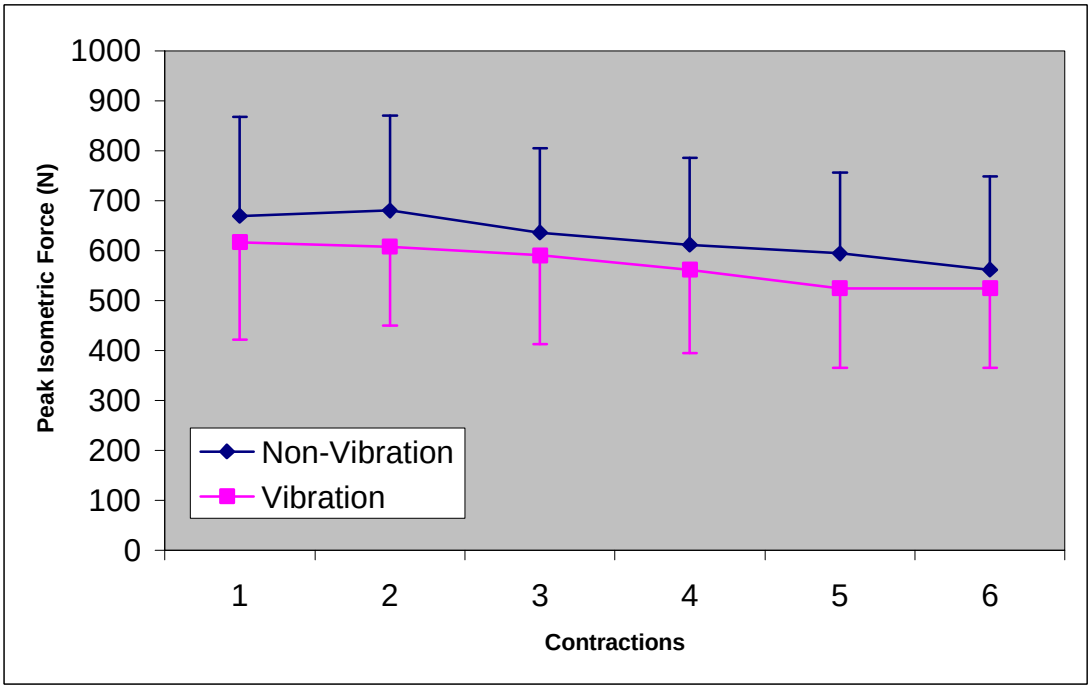

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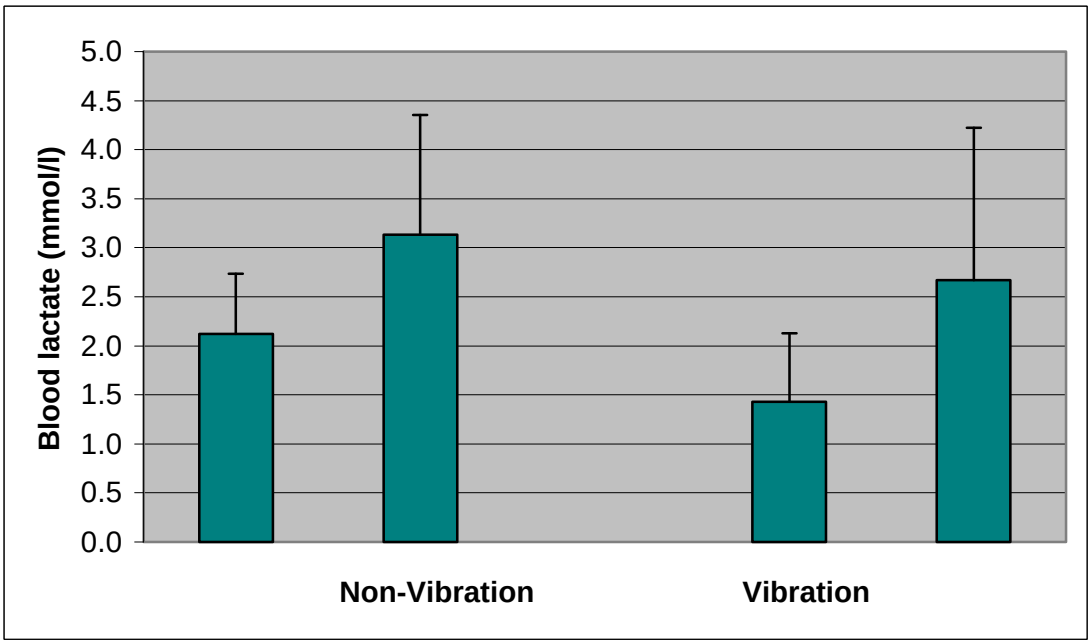

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