INTRODUCTION
Metabolic rates can increase 12 and 21 times above resting levels in untrained and trained cyclists respectively [1]. The majority of this increase can be attributed to the energy demand from leg muscle contractions. This in turn affects muscular efficiency since the coordination and timing of leg muscle activation is reflected in the mechanical work and power output of the cyclist [2].

When analyzing mechanical efficiency in cycling the metabolic costs have been estimated through oxygen/ carbon dioxide exchange [3] where the energy utilized by the working leg muscles reflects the changes in oxygen consumption (VO₂) [4]. Gas exchange measures of metabolic work are unable to resolve the metabolic cost on a cycle by cycle basis during rapid pedalling, although we know that cycle-by-cycle changes in activity affect the cycling efficiency [2].

Studies have compared electromyography (EMG) from the vastus lateralis to VO₂ and found both linear and non-linear relationships [5]. Recently, we showed a significant monotonic increase in metabolic power associated with increased EMG intensity using ten leg muscles while cycling [6]. The purpose of this study is to improve the predictions of metabolic cost based on EMG, and to determine how much information about metabolic power can be derived from the EMG.

METHODS
Periods of three-minute steady state cycling were performed at ten evenly spaced workloads between 30 and 90% of the power output at maximum VO₂. Surface EMG from ten leg muscles as well as oxygen and carbon dioxide gas exchange were monitored throughout the test.

The EMG was resolved into intensities (I_EMG) [7]. Total EMG intensity (I_tot) was given by the sum of I_EMG across all muscles for each pedal cycle and normalized for each muscle by intensities attained during a dynamic sprint test completed at the beginning of the test. Metabolic power was estimated from the gas exchange data for each breath and the mean I_tot between breaths was used to acquire a I_tot value per breath. Cross correlation was used to identify the highest correlation between I_tot and metabolic power assuming there is a delay between the EMG signal and subsequent oxygen consumption.

RESULTS AND DISCUSSION
The correlation was highest with a mean delay in metabolic power of 44 seconds across all workloads (r=0.89; Figure 1). This delay is consistent with previously recorded on-transient pulmonary oxygen uptake response times during cycling [8]. The correlation was an improvement on the correlation found previously (r=0.86; [6]), with the major differences in methodology being the normalization of the EMG, and the time offset between the EMG activity and the gas exchange measures of metabolic power.

It is reasonable to suggest that larger muscles can place a greater metabolic load on the body than smaller muscles. It is thus possible that weighting the EMG intensities by the muscle volume may further improve the relationship between EMG and metabolic power.

This study shows that I_tot across ten leg muscles is a reasonable estimate of metabolic power at workloads where VO₂ would traditionally be used (predominantly aerobic). This is an important finding as it allows for estimates of metabolic cost on a cycle-by-cycle basis using EMG. This approach will make possible future studies that relate changing coordination patterns with cycling efficiency. Furthermore, these methods may also provide valuable information at predominantly anaerobic workloads as muscle activity does not discriminate the energy source.

Figure 1: Total EMG intensity across 10 leg muscles versus metabolic power on a breath-by-breath basis.

REFERENCES