Performance and physiological consequences of roll dynamics during cross-country mountain bike racing.

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STUDENT DECLARATION

I hereby declare that this thesis is my own work and does not, to the best of my knowledge, contain material from any other source unless due acknowledgement is made. The thesis was completed under the guidelines set out by Massey University's College of Health, for the degree of Doctorate of Philosophy and has not been submitted for a degree or diploma at any other academic institution.

Candidate: ………………………………………………………..

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ABSTRACT

Background: Understanding the interaction between physical work done and subsequent physiological responses is key to the prescription of optimal training. Olympic format cross-country mountain bike racing presents unique challenges with regards to understanding the relationship between propulsive and non-propulsive work, the interaction with performance, and associated physiological responses.

Aims: The aims of this thesis were to: 1) Determine the nature of work demand during simulated cross-country mountain bike racing; 2) Quantify vibration exposure during cross-country mountain biking and the interaction of bike-body in the subsequent energy dissipation; 3) Establish additional work done and physiological responses to riding on surface-terrain variations; 4) Investigate technological interventions designed to reduce vibration exposure during cross-country mountain biking and the interaction with performance and cycling economy.

Methods & Results: To address these aims four original experimental investigations involving two descriptive elements and four experimental interventions were conducted.
Study 1: Participants (n=7) completed a submaximal treadmill test on bicycles in order to establish the power:oxygen uptake relationship, which when combined with an ergometer maximal ramp test, enabled the prediction of oxygen demand during the field and thus estimations of aerobic and anaerobic contributions to work done. Field work involved particpants riding at race pace on a cross-country mountain bike course whilst cadence, power output, oxygen consumption, heart rate, speed and geographical position were recorded. The data show power output and cadence to be highly variable with one power surge every 32 s and a supramaximal effort (greater than power associated with $\dot{V}O_{2\,max}$) every 106 s. The majority of time (20.7 ± 8.3 %) was spent pedalling at a low velocity-high force, whilst physiological

variables % $\dot{V}O_{2\,max}$ (77 ± 5 %) and % HR_{max} (93 ± 2 %) were consistantly elevated to a high level throughout the lap. Importantly, the results identified that terrain significantly affecteded power output (70.9 7.5 vs 41.0 ± 9.2 % W_{max}); % $\dot{V}O_{2\,max}$ (80 ± 2 vs 72 ± 4 %) but not % HR_{max} (94 ± 2 vs 91 ± 1 %) for uphill and downhill, respectively. Accordingly, it was hypothesised that there was an additional non-propulsive physical stress during downhill riding, affording less recovery compared to road cycling.

Study 2: Participant (n=8) completed one lap of a cross-country track at race pace under two conditions (26” vs 29” wheels) whilst tri-axial accelerometers located on the bicycle (handlebar and seatpost) and the rider (wrist, ankle, lower back, and forehead) recorded accelerations (128 Hz) to quantify vibrations over the whole lap and for terrain specific sections (uphill vs downhill). The result showed that significant vibration attenuation occurred from locations at the bike and bike-body interface compared to the lower back and forehead. The reduction of accelerations at the lower back and forehead implies additional non-propulsive, muscular challenges which may limit recovery during periods of non-propulsive load.

The hypothesis that 29” wheels would reduce vibration exposure was inconclusive as 29” wheels proved to be significantly quicker (p=0.0020) compared to 26” wheels even though no difference was found between power output (p=0.3062) and heart rate (p=0.8423). As such the greater velocity incurred by 29” wheels may have caused the greater vibration exposure seen in the 29” wheels.

Study 3: Participants (n=7) ascended a tar-sealed road climb and a singletrack off-road climb of identical length and gradient at the same speed. Tri-axial accelerometers (128 Hz) located at the handlebar, wrist, ankle, seat post, lower back, and forehead were used to quantify vibration exposure while power output , cadence, heart rate and oxygen consumption were used to determine work done and physiological cost. Accelerations signified (P<0.0001) greater vibration exposure for off-road compared to tar-sealed riding and post-hoc analysis identified differences at the bike and bike-body interface but not the lower back and forehead. This indicates a greater non-propulsive component in the form of vibration damping to off-road cycling compared to road cycling, reflected by significant increases in work done (280 ± 69 vs 312 ± 74 W; $p=0.0003$). This was associated with a greater rate of oxygen consumption (48.5 ± 7.5 vs 51.4 ± 7.3 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; $p=0.0033$) and a higher heart rate (161 ± 10 vs 170 ± 10 bpm; $p=0.0001$) for tar-sealed road and off-road conditions, respectively. These findings advocate that technological interventions aimed at decreasing vibration exposure could increase cycling economy and therefore improve performance.

Study 4: Participants (n=8) completed a lap of a cross-country mountain bike circuit under two conditions (hardtail and full suspension) incorporating the same downhill section twice and separated by a forestry road climb. The particpants were asked to complete the downhill sections at race pace while the climb was performed at a power output associated with respiratory compensation point. The aim of this was to control physiological variables at the start of the second downhill. Tri-axial accelerometers (located at the handlebar, wrist, ankle, seat post, lower back, and forehead) were used to quantify vibration exposure while simultaneous power output , cadence, heart rate and oxygen consumption measurements enabled assessment of work done and physiological response. Performance was determined by time to complete the overall lap and specific sections.

Physiological demand of loaded downhill riding (2nd descent) was greater than unloaded (1st descent) ($p<0.0001$). Full suspension decreased total vibration exposure ($p<0.01$) but had no effect on performance times ($p=0.9697$) or power outputs ($p=0.8600$) whilst post-hoc analysis identified trial differences (downhill 1 vs downhill 2) in power output ($p<0.0001$) but not for time ($p>0.05$). Interestingly, the reduction of non-propulsive work did not affect oxygen consumption ($p=0.9840$), heart rate ($p=0.9779$) or cycling economy ($p=0.9240$).

Conclusions: This thesis demonstrates that surface-terrain negatively affectss cycling economy, presenting greater physiological responses as a consequence of increased non-propulsive work. This is likely due to vibration damping throughout the soft tissue of the limbs in order to protect the central nervous system. Reductions in vibration exposure diminished work done and physiological response for surface controlled interventions, yet mechanical system modifications capable of reducing exposure were unable to alter physiological response to work done.

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ABBREVIATIONS

ANOVA:	Analysis of Variance
AT:	Anaerobic Threshold
BM:	Body Mass
BMI:	Body Mass Index
BPM:	Beats per minute
CV:	Coefficient of Variation
DH:	Downhill
H:	Hill
HR:	Heart Rate
IAT:	Individual Anaerobic Threshold
ISO:	International Standard Organisation
MTB:	Mountain Bike
O_2:	Oxygen
OBLA:	Onset of Blood Lactate Accumulation
Off-Rd:	Non-smooth (tar-sealed) surface
RCP:	Respiratory Compensation Point
Rd:	Road (tar-sealed)
RMS:	Root Mean Squared
rpm:	revolutions per minute
SD:	Standard Deviation
UCI:	Union Cycliste Internationale
$\dot{V}O_2$:	Volume of Oxygen utilised per minute in time
W_{max}:	The maximal power output obtained over a 60 s epoch durng a cycle ergometry ramp test
XCO-MTB:	Olympic Format Cross-Country Mountain Biking

SUBMISSIONS AND PUBLICATIONS

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