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Quantification and description of braking during mountain biking using a novel brake power meter

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

in

Sport & Exercise Science

at Massey University, Palmerston North, New Zealand.

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Bachelor of Science in Exercise Science

Master of Science in Exercise Science

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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. This thesis was completed under the guidelines set by Massey University's College of Health, for the degree of Doctor of Philosophy and has not been submitted for a degree or diploma at any other academic institution.

Candidate: ____________________________________

Date: ____

Foreword

When I came to New Zealand to do my PhD, I wasn't very sure of what I wanted to study. I knew I wanted to study mountain biking, but it's such a diverse sport with many genres, and I really had no clear direction of where my studies would go. However, one thing was for sure: I was in the right place!

My supervisory team had what I felt was a good mixture of specialities within Sport & Exercise Science, and the further I went through my research, the more I understood the perfect mixture of talent surrounding me. Strangely, while this same team had previously paved the way to new ideas in mountain biking research, I was given full liberty to shape my own ideas and make my own mistakes.

The brake power meter idea was born during an actual mountain bike competition. I found myself racing against my supervisor, Steve, who was much more fit than myself. As we continued the race and I could hear Steve's squeaky brakes, I knew the only reason I was able to keep up with him was for not braking myself.

Rather than being told it was a silly idea to measure braking for my PhD, I was taught how to apply for funding, given advice on what kind of variables we should measure, and had conversations on how we might run experiments. It was these kinds of events that taught me the depth of expertise and highly innovative scientists I'm surrounded by.

I’ve been tested more than I ever expected throughout this process, but have gained knowledge and experience beyond that of sports experiments.

Thank you for believing in me.

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Thank you to my family and friends for motivating me and assuring me that this process will be worth it in the end. GUNAX LBH GB ZL FGVAXL.

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This is for the haters.

Publications & Presentations

Publications

Miller, M. C., Fink, P. W., Macdermid, P. W., & Stannard, S. R. (2017). Validation of a normalized brake work algorithm designed to output a single metric to predict non-propulsive mountain bike performance. (IN REVIEW).

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Matthew C. Miller, Philip W. Fink, Paul W. Macdermid, Steven R. Stannard (2017). The utilization of a bicycle brake power meter for cross-country mountain biking. Australian Strength and Conditioning Association, Gold Coast, Australia, 10-12 Nov

Matthew C. Miller, Paul W. Macdermid, Philip W. Fink, Steven R. Stannard (2016). Performance and physiological effect of different pacing strategies for mountain bike racing. European College of Sports Science, Vienna, Austria, July 9

Matthew C. Miller, Chad A. Witmer, Gavin L. Moir, Shala E. Davis (2014). The Predictive Validity of Critical Power and Functional Threshold Power for Mountain Bike Race Performance. Tsukuba Summer Institute, Tsukuba University, Japan, July 23

Matthew C. Miller, Chad A. Witmer, Gavin L. Moir, Shala E. Davis (2014). The Predictive Validity of Critical Power and Functional Threshold Power for Mountain Bike Race Performance. ACSM Annual Meeting, Orlando, FL, USA May 27-31

Emily J. Sauers, **Matthew C. Miller**, Benjamin Sina, Bryce J. Muth, Brandon W. Snyder, Shala E. Davis (2014). Effects of Full-fat and Fat-free Chocolate Milk On Recovery Following Endurance Running. ACSM Annual Meeting, Orlando, FL, USA May 27-31

Abstract

Olympic format cross country mountain biking is both physically and technically demanding. The demands of this cycling genre are in contrast to road cycling because of the demanding off-road terrain. With its many obstacles and different surfaces, riders must make their way up and over steep hills a number of times throughout a lap. It's very easy to be able to measure the performance of the riders on ascending sections of the track thanks to on-the-bike personal power meter that measure the propulsive work rates in the pedals. However, there is currently no commercially available method to assess the way the rider handles the bike on descending sections. This thesis first highlighted the differences in physiological demand of descending on off-road versus on-road (**Chapter 4**). An interesting finding in **Chapter 4** also showed that riders might be able to save energy by adopting a coasting strategy down hills. This caused the researchers to question the bicycle handling attributes that might allow this, which led to the development and validation of a device designed to measure how the rider uses the brakes while riding/racing (**Chapter 5**). From there, we completed an investigation akin to the early mountain biking descriptive studies (**Chapter 6**), but instead of focusing on data related to respiratory and metabolic load, the brake power meter was employed. The finding that braking patterns were related to mountain biking performance was not surprising, but being the first team to quantify this was very exciting. Since most of the braking was occurring on the descents in that study, we examined the differences in braking between training groups on an isolated turn (**Chapter 7**). The finding that inexperienced riders use their brakes differently—and that this results in reduced performance—left no doubt to the importance of braking. From there, we revisited the method used to calculate rear brake power, since current methods led to inaccurate measurement during skidding

(**Chapter 8**). This thesis culminated with the exploration of an algorithm that could quickly and easily describe mountain bike descending performance with one single metric (**Chapter 9**); the hope is that the normalized brake work algorithm should increase the utility of the brake power meter for training purposes and post-competition performance analysis. Overall, this thesis highlights the need, importance and utility of a bicycle brake power meter to assess mountain bike performance.

List of Abbreviations

ANOVA – analysis of variance

AT – aerobic threshold

CP – critical power

DH – downhill (descending) terrain

E_K – kinetic energy

F - force

FTP - Functional threshold power

HR – heart rate

I - inertia

IP – intermittent power

J - joule

LT – lactate threshold

FLAT – flat terrain

m – meters

ω (omega) – angular velocity

OBLA – onset of blood lactate

r - radius

RCP – respiratory compensation point

rad - radians

RMS – root mean square

s - seconds

SD – standard deviation

t – time

τ - torque

TRIMPS – training impulse

UP – uphill (ascending) terrain

v - velocity

VO_2 – volume of oxygen uptake

W – watt

W^1 – anaerobic work capacity

XCO-MTB – Olympic format cross-country mountain bike racing

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