

# **Athlete monitoring in professional Australian football: Measurement characteristics, parsimony and relationships with performance**

by **Samuel Ryan**

Thesis submitted in fulfilment of the requirements for  
the degree of

**Doctor of Philosophy**

under the supervision of

Distinguished Professor Aaron Coutts  
Professor Franco Impellizzeri  
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## ***Certificate of Authorship and Originality of Thesis***

I, Samuel Ryan, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Health at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

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Signature removed prior to publication.

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**Samuel Ryan**

22/01/2021

**Date Submitted**

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*If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health.*

Hippocrates.

*The more comfortable we become with being stupid, the deeper we will wade into the unknown and the more likely we are to make big discoveries.*

Schwartz M. The stupidity of scientific research. *Journal of Cell Biology*. 2008;121:1771.

## *Preface*

This thesis is for the degree of Doctor of Philosophy and is in the format of conventional thesis. The thesis abides by the 'Procedures for Presentation and Submission of Theses for Higher Degrees – University of Technology, Sydney; Policies and Directions of the University'.

The data collected by the candidate has resulted in five manuscripts being published in peer-reviewed journal articles. In addition, the thesis contains two manuscripts that have not been submitted for peer-review. The thesis begins with an introduction to provide a background to the research problem, followed by two literature reviews which in combination provide an overview of training monitoring and measurement characteristics of athlete monitoring tests in professional Australian football, and highlight gaps in current research pertinent to the stated research problems to be addressed in the thesis. Each study that follows is presented in manuscript form, including an introduction section, methods section, statistical analyses section, results section, discussion section and conclusion with practical applications. Figures and tables appear in the thesis within each manuscript as they appear in publication. A general discussion chapter is presented following the final study, reviewing and integrating the main findings of the thesis with previous research and associated limitations of the investigations. The final chapter provides a summary of the contribution of the thesis and directions for future research. Journal of the American Medical Association (JAMA) referencing style is used throughout the thesis, with a list of references provided in Chapter Eleven.

### ***List of manuscripts submitted for publication***

**Ryan, S.,** Kempton, T., Impellizzeri, F., & Coutts, AJ. (2020). Training monitoring in professional Australian football: theoretical basis and recommendations for coaches and scientists. *Journal of Science and Medicine in Football.* 4(1);52-58. [Doi:10.1080/24733938.2019.1641212.](https://doi.org/10.1080/24733938.2019.1641212)

**Ryan, S.,** Pacecca, E., Kempton, T., & Coutts, AJ. (2019). Measurement properties of an adductor strength-assessment system in professional Australian footballers. *International Journal of Sports Physiology and Performance.* 14(2), 256-259. [Doi: 10.1123/ijsp.2018-0264.](https://doi.org/10.1123/ijsp.2018-0264)

**Ryan, S.,** Pacecca, E., Tebble, J., Hocking, J., Kempton, T., & Coutts, AJ. (2020). Measurement characteristics of athlete monitoring tools in professional Australian football. *International Journal of Sports Physiology and Performance.* 15(4); 457-463. [Doi: 10.1123/ijsp.2019-0060.](https://doi.org/10.1123/ijsp.2019-0060)

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**Ryan, S.,** Crowcroft, S., Kempton, T., & Coutts, AJ. (2020). Associations between refined athlete monitoring measures and individual match performance in professional Australian football. *Journal of Science and Medicine in Football.* Published Ahead of Print. [Doi: https://doi.org/10.1080/24733938.2020.1837924](https://doi.org/10.1080/24733938.2020.1837924)

## ***Conference proceedings and abstracts***

**Ryan, S.,** Pacecca, E., Tebble, J., Hocking, J., Kempton, T., & Coutts, AJ. (2019, June 4-7).

Measurement characteristics of athlete monitoring tools in professional Australian football.

*Presented at the 9<sup>th</sup> World Congress of Science and Football, Melbourne, Australia.*

## *Statement of candidature contribution*

*Table 1.1: Percentage contribution of authors to peer-reviewed manuscripts of thesis.*

Author	Study One (Chapter Four)				Author	Study Two (Chapter Five)					
	Sam Ryan	Emidio Pacecca	Thomas Kempton	Aaron Coutts		Sam Ryan	Emidio Pacecca	Jye Tebble	Joel Hocking	Thomas Kempton	Aaron Coutts
Research design	70%	10%	10%	10%	Research design	70%	5%			5%	20%
Ethics application	70%			30%	Ethics application	70%					30%
Data collection	80%	20%			Data collection	65%	5%	20%	10%		
Data cleaning	100%				Data cleaning	100%					
Statistical analysis	90%			10%	Statistical analysis	100%					
Manuscript preparation	100%				Manuscript preparation	100%					
Manuscript revision	50%		20%	30%	Manuscript revision	50%				20%	30%

  

Author	Study Three (Chapter Six)			Author	Study Five (Chapter Eight)			
	Sam Ryan	Thomas Kempton	Aaron Coutts		Sam Ryan	Stephen Crowcroft	Thomas Kempton	Aaron Coutts
Research design	80%	10%	10%	Research design	80%		10%	10%
Ethics application	70%		30%	Ethics application	70%			30%
Data collection	90%	10%		Data collection	90%		10%	
Data cleaning	100%			Data cleaning	100%			
Statistical analysis	90%		10%	Statistical analysis	60%	30%	10%	
Manuscript preparation	100%			Manuscript preparation	100%			
Manuscript revision	50%	20%	30%	Manuscript revision	50%	20%	10%	20%



## ***Thesis Abstract***

Australian football (AF) is a physically-demanding, high-intensity field-based sport with players competing in the presence of performance-related psychological stress. This requires detailed monitoring of players for training and competition to maximise their readiness for high-level performance. Historically, monitoring team sport athletes has been based on the theoretical ‘fitness-fatigue’ model whereby performance can be deduced with knowledge of fitness (positive effects of training completed) and fatigue (residual impairments of function due to an acute training dose) over acute (~15 days) and chronic timeframes (~50 days). However, in practice, individual training load is prescribed to players over acute timeframes of ~7 days prior to competition matches, dictated by scheduling of matches every 6-8 days during the competition season. The prescription of acute training load is informed by a range of athlete monitoring data measuring training load completed, training response and neuromuscular performance. However, despite anecdotal evidence of the use of individual acute training load prescription in professional AF, it has not been presented empirically. This thesis contains five studies that aim to build a novel conceptual model of acute training load prescription using a refined collection of monitoring tests with suitable measurement characteristics that relate to competition performance in professional AF. *Study One* and *Study Two* evaluated the measurement characteristics of reliability and sensitivity of common tests of training response, neuromuscular performance and aerobic fitness using test-retest and signal-to-noise ratio methods. The results showed that perceived wellness questionnaires, countermovement jump tests, eccentric hamstring force tests, isometric adductor force tests and heart rate recovery tests possess acceptable reliability and sensitivity, allowing confident identification of meaningful test results for practitioners. *Study Three* and *Study Four* addressed the issue of monitoring data overload for team sport practitioners by applying principal component analyses (PCA) to the monitoring tests established in *Study One* and *Study Two* in addition to measures of training

load and extended this analysis to propose two practical methods of using the results of PCA to enhance efficiency in team sport monitoring systems. *Study Three* demonstrated that external load, internal load and perceived wellness represent statistically separate constructs of the training process, across acute (7-day) and chronic (28-day) timeframes commonly used to categorise athlete monitoring data. *Study Four* identified components to represent isometric adductor force, eccentric hamstring force and countermovement jump power. These findings indicate that many individual measures commonly collected and analysed in professional team sport monitoring systems assess similar aspects of the training process, and hence some variables can be excluded from monitoring systems to enhance efficiency in the use of financial and human resources. *Study Five* analysed the effect of a refined collection of measures of training load, training response and neuromuscular output from previous studies in the thesis and showed that z-score increases in individual acute training load associated with an 18-23% increase in performance z-score. This finding indicates that team competition schedule may have a confounding effect on acute load completed prior to a match as longer between-match periods provide for opportunity and flexibility for greater load completion. *Study Five* also found no significant relationships between a range of other commonly collected monitoring variables and performance change. Collectively, the thesis populated a novel conceptual model of acute training load prescription with individual adjustments of acute load informed by a refined range of reliable and sensitive monitoring measures that relate to individual performance changes.

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## *Abbreviations*

AF	Australian football
AFL	Australian Football League
AU	arbitrary units
AUC	area under the curve
$\beta$	beta
bpm	beats per minutes
CI	confidence interval
cm	centimetres
CMJ	countermovement jump
CV	coefficient of variation
d	day
ES	effect size
Exp( $\beta$ )	beta exponent
GPS	global positioning system
h	hours
HRex	heart rate during exercise
HRR	heart rate recovery
HSR	high-speed running
Hz	hertz
ICC	intraclass correlation coefficient
IMA	inertial movement analysis
Kg	kilograms
km·h <sup>-1</sup>	kilometres per hour

LPS	local positioning system
m	metres
m/s	metres per second
MCIC	minimal clinically important change
mm	millimetres
MTP	mid-thigh pull
N	Newtons of force
N/kg	Newtons per kilogram
PC	principal component
PCA	principal component analysis
QIC	quasi-likelihood independence model criterion
ROC	receiver operating characteristic
RPE	rate of perceived exertion
RSImod	reactive strength index modified
s	second
SD	standard deviation of the mean
SNR	signal-to-noise ratio
SRPE	session rate of perceived exertion
SWC	smallest worthwhile change
TD	total distance
TE	typical error
TRIMP	training impulse
VHSR	very high-speed running
W/kg	watts per kilogram