UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Monitoring in Elite Youth Soccer: Describing Load, Reducing Data and Assessing its Relationship with Physical Fitness Outcomes

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A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy (Sport and Exercise)

Under the supervision of:

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Certificate of Original Authorship

I, Darragh Robert Connolly declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy (Sport and Exercise), 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 is 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 and the Juventus Football Club (Italy).

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Preface

This thesis for the degree of Doctor of Philosophy is in the format of Thesis by Compilation following the 'Graduate Research Candidature Management, Thesis Preparation and Submission Procedures'.

The current thesis presents a collective body of studies that are published or prepared for submission in scientific journals. Study one is accepted and published in the Journal of Strength and Conditioning Research. Studies three to six are currently in preparation for journal submission. This thesis contains a general introduction that details the background to load monitoring in team sports and the importance of this process in youth soccer before stating the key objectives for each study (chapter one). A systematic review is included to provide a comprehensive overview of the current evidence as it relates to the relationship between training dose and the outcome response to training in elite youth soccer players (chapter two). The main body of research is presented in chapters three to seven, in the form of six original investigations. Collectively, these studies combine to describe the load performed by elite youth-level soccer players and establish the constructs of load that describe the greatest amount of variance within a player monitoring dataset. The general discussion provides an interpretation of the studies from a practical standpoint and details clear implications for sports scientists and researchers working in the elite youth football academies. The final section of this thesis provides an interpretation of the collective findings and suggests practical recommendations that help to guide areas that researchers can further investigate. All references are included in the reference list at the end of the thesis.

Finally, the impact of the COVID-19 pandemic should also be acknowledged. Specifically, the prolonged lockdown periods, inability to travel internationally, the new work organization at Juventus (i.e., COVID bubbles, etc.), and increased work demands required to manage these factors severely affected the original research.

List of Publications

Peer-reviewed journal articles

Connolly, D.R., Stolp, S., Gualtieri, A., Ferrari Bravo, D., Sassi, R., Rampinini, E., and Coutts, A.J. (2022) How do young soccer players train? A 5-year analysis of the training load and its variability in an elite youth academy. *Journal of Strength and Conditioning Research*. in press

Connolly, D.R., Rampinini, E., and Coutts, A.J. (2022) The influence of training load on fitness and performance outcomes in elite youth soccer players: a systematic review. *Sports Medicine - Open*. in preparation.

Connolly, D.R., Stolp, S., Gualtieri, A., Ferrari Bravo, D., Sassi, R., Rampinini, E., and Coutts, A.J. (2022) How do young soccer players train? A 5-year analysis of the differences in weekly micro-cycle training load across an elite youth academy. *International Journal of Sports Physiology and Performance*. in preparation.

Connolly, D.R., Stolp, S., Rampinini, E., and Coutts, A.J. (2022) Rating of perceived exertion in elite youth soccer players: What variables contribute the most? *Journal of Strength and Conditioning Research*. in preparation.

Connolly, D.R., Stolp, S., Rampinini, E., Coutts, A.J., (2022) Training load variables in elite youth soccer: is a data reduction approach consistent across different age groups? *International Journal of Sports Medicine*. in preparation.

Connolly, D.R., Stolp, S., Rampinini, E., Coutts, A.J., (2022) Identifying training load variables through a conceptual framework for elite youth soccer. *International Journal of Sports Medicine*. in preparation.

Connolly, D.R., Mercer, M., McLean, B., Rampinini, E., Coutts, A.J., (2022) Assessment of dose-response relationships between 1-week and 4-week cumulative training load and physical performance outcomes in elite youth soccer. *Science and Medicine in Football*. in preparation.

Conference proceedings

Connolly, D., Stolp, S., Gualtieri, A., Ferrari Bravo, D., Sassi, R., Rampinini, E., Coutts, A.J. (2022) How do young soccer players train? A 5-year analysis of elite academy players weekly training load and its distribution across a micro-cycle. *World Congress on Science and Soccer*. Coimbra, Portugal

Connolly, D., Stolp, S., Rampinini, E., Coutts, A.J., (2022) Training load variables in elite youth soccer: Is a data reduction approach consistent across different age groups? *World Congress on Science and Soccer*. Coimbra, Portugal

Abstract

Soccer is a team-based sport that requires prolonged high-intensity intermittent exercise and the execution of numerous different actions that elicit high levels of force. The stochastic nature of these phases requires players to stress a range of different physical capabilities. Developing these physical abilities concurrently (i.e., alongside technical, and tactical training) poses a significant challenge in managing players training loads, and therefore requires a systematic approach to training design and management. The widespread use of player monitoring tools and quantity of data provided by micro-technology requires a greater understanding which parameters should be examined and also the variation that can occur in these parameters through a competitive season. The objective of this thesis was to aid practitioners by conducting an in-depth analysis of real-world data and applied scenarios that occur in an elite level academy. A specific objective was to assess and provide insights into the differences (if any) between different age groups and contribute towards advancing current knowledge regarding "how they train" and the evolution of players physical capacities. This thesis contains 7 independent studies which aim to describe the training loads incurred by elite-level youth soccer players, identify the constructs that can help to prescribe training, remove data redundancy by identifying the variables that parsimoniously describe the training load performed, and finally, describe the association between select training load variables and physical outcomes in this specific population.

Study one was a systematic literature review that investigated the relationship between training load variables and the performance outcomes in youth soccer players. The main findings highlighted that a limited number of studies (n = 10) reported inconsistent relationships for both aerobic and neuromuscular capabilities. Whilst there was low to moderate risk of bias in previous studies, the present analysis showed these studies findings were imprecise, inconsistent, and indirect. The review highlighted the need for additional research examining the associations between select training load variables (over acute and chronic periods) based on well justified conceptual frameworks and consistent reporting methods.

The second study examined the levels of training load accrued accumulated during in-season training weeks in four age groups (i.e., U15, U16, U17, and U19) of an elite youth soccer academy. The results present a progression in players perceived training load levels from U15 to U17, with a subsequent reduction in load in the U19. This study also presented differences in the levels of training load performed between starters and non-starters and a limited degree of variability between training

weeks. Study three described how these training loads were distributed across a weekly microcycle in the different age groups of an elite youth soccer academy. Results showed that the match day was the most intense session of the training week across all age groups and the application of a different weekly training load distribution in the youngest and oldest age groups of the academy. Study four investigated which training metrics provided by wearable microtechnology during training and competition influenced the players sRPE. This study identified that total distance, very high-speed running, and a moderate heart rate threshold to be the major contributors to sRPE.

A practical problem for sports scientists assessing training load in soccer is handling the vast array of data being recorded from each session for each player. Therefore, studies five and six applied two different approaches to applying Principal Component Analysis (PCA) on a dataset consisting of 82 training load variables to identify components and/or variables that described the most variance in the training load. Study five used an unguided approach and study six used a guided approach. This process was also undertaken to ensure that the metrics included in the academy's training load monitoring program were not omitting a variable (or group of variables) that could aid training prescription, or alternatively including unnecessary variables in the training load analysis. The results of study five demonstrated that, when unguided variable input was used for the PCA, numerous variables are required to describe training load and that the PCA outputs were subtly different in each of the four different age groups. In addition, after data reduction (i.e., PCA), 7 components and 25 variables were retained in study five, and these results were deemed to have limited practical applications for interpreting training load in an applied setting. Therefore, in study six, a conceptual framework based on current literature and expert opinion was then developed and applied to guide training load variable selection in a follow-up PCA. The results of study six identified four components of load (i.e., the total volume of load, acceleration load, the quantity of high-speed running, and heart rate load), including both internal and external load, that should be considered in a load monitoring program. The variance described was relatively stable across the four components, despite differences in the weighting of different variables in some of the age groups.

The final study (study seven) assessed the dose-response relationship between select training load variables with fitness outcomes (i.e., aerobic fitness, high-intensity intermittent running capacity, and neuromuscular power) across three different age categories. The results demonstrate that age group and test period influence both physical outcomes and the quantity of load performed in that phase of the competitive season. We observed that changes in aerobic fitness was not related to the quantity

of load accumulated over 1- or 4-week periods for any load variable. In contrast, both acute (1-week) and chronic (4-week) sRPE and very high-speed running training loads were shown to be associated with improvements in countermovement jump power values.

The collective findings in this thesis provide a new detailed description of the quantity and distribution of sRPE training load performed by elite youth soccer players, highlighting the importance of controlling training duration to manage training load and identify contextual factors that influence periodisation strategies. The present results also question the efficacy of applying PCA as a data reduction method to agnostically identify constructs of training loads for the purposes of player monitoring. The findings also highlight the complex nature of the dose-response relationship between training load variables and fitness outcomes. Additionally, the results of each individual study highlight subtle differences between age groups, their periodization strategy and trends in the evolution of players physical capacity. Key learnings for practitioners are provided through demonstrating an evidence-informed approach to player monitoring and show how the importance of various player monitoring data can be assessed through the research process. Collectively, the findings of this thesis support the application of a conceptual framework for the identification of suitable training load constructs and the metrics to be included in a training load monitoring system for elite youth soccer players. Indeed, it is recommended that practitioners and scientists embrace the uncertainty and individual differences that exists in the complex system of training youth footballers. These findings can be used to refine and enhance the approach to player monitoring in a world class youth academy, but with the acknowledgement the there is a complex relationship between training loads and outcomes in elite youth football. Further research is required to identify other methods that can provide practical insights to the monitoring process and facilitate players long-term development.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

%	Percentage
30ASR	30% anaerobic speed reserve
ACC	Accelerations
AD	Acceleration distance
AIC	Akaike information criterion
ANOVA	Analysis of Variance
AU	Arbitrary units
CI	Confidence interval
CMJ	Countermovement Jump
CMJA	Countermovement Jump with arm swing
CMJD	Countermovement jump with single dominant leg
CMJnD	Countermovement jump with single non-dominant leg
CR	Category ratio
CV	Coefficient of variation
DEC	Decelerations
d	Cohen's d effect size
df	Degrees of freedom
EPPP	Premier League's Elite Player Performance Plan
ES	Effect size
FIFA	Internationale de Football Association
GPS	Global Positioning System
GTG	Generic training group
h	hour
HIT	High Intensity Intermittent running test
HR	Heart rate
HR85-90%	Time spent between 85% and 90% of heart rate max
HR90%	Time spent above 90% of heart rate max
HRmax	Heart rate max
HSD	High-speed distance
HRE	Heart rate exertion
HSR	High-speed running
IN1	Beginning of the competitive season
IN2	Halfway through the competitive season
IN3	Before the final stage and play-offs
ISRT	Intermittent shuttle running test
iTRIMP	Individualized training impulse
kg	Kilogram
km	Kilometre

KMO	Kaiser-Meyer-Olkin
Lac	Blood lactate accumulation
LT	Lactate threshold
LTHR	Heart rate at lactate threshold
LTAD	Long-Term Athlete Development
m	Metre
m>MAS	Distance covered above maximum aerobic speed
MAS	Maximal aerobic speed
MD	Matchday
MD-x	x-days before the next match
min	Minute
mmol/L	millimole per litre
MSS	Maximal sprint speed
n	Number / Sample size
NRCT	Non-randomized control trial
OBLA	Onset of blood lactate accumulation (4.0 mmol/L)
OBLAHR	Heart rate at onset of blood lactate accumulation
OSF	Open Science Framework
p	P-value
PC	Principal component
PCA	Principal component analysis
PRE	Preseason training
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews
PVT-CAR	Peak velocity derived from the Carminatti test
r	correlation coefficient
ROBINS-I	Risk of Bias in Non-randomized studies of Interventions
RPE	Rating of perceived exertion
RSA	Repeated sprint ability
SD	Standard deviation
SE	Standard error
SJ	Squat Jump
SPR	Sprint
SPSS	Statistical Package for the Social Sciences
sRPE	Session Rating of perceived exertion
sRPEmus	Muscular rating of perceived exertion
sRPEres	Respiratory rating of perceived exertion
STG	Specific training group
SWC	Smallest worthwhile change
t>MAS	Time spent above maximum aerobic speed
t>30ASR	Time spent above 30% anaerobic speed reserve

T-CAR	Carminatti Test
THIR	Total high-intensity-running distance
TD	Total distance
TL	Training Load
TLd	Training duration
TRIMP	Training Impulse
UEFA	Union of European Football Associations
UMTT	Université de Montreal track test
v	Velocity
V3	Running velocity with a blood lactate accumulation of 3 mmol/L
VHSD	Very high-speed distance
VHSR	Very high-speed running
VO_2max	Maximal Oxygen Consumption
VHSR	Very high-speed running
W	Watts
YYIRT1	Yo-yo intermittent recovery level 1