

**NEUROMUSCULAR, BIOCHEMICAL,  
ENDOCRINE AND PHYSIOLOGICAL  
RESPONSES OF ELITE RUGBY  
LEAGUE PLAYERS TO COMPETITIVE  
MATCH-PLAY.**

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## DECLARATION

This work has not previously been submitted for a degree or diploma in any University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Signed: \_\_\_\_\_

Christopher P. McLellan

## **PREFACE**

In 2009, the National Rugby League (NRL) was the most watched sport on Australian television (TV) (403). A review of TV ratings at the completion of the 2009 NRL season revealed that 60 of the top 100 rating subscription TV programs were NRL matches (403), exceeding TV ratings of all other football codes in Australia. In particular, NRL matches out-rated Australian Football League (AFL) matches on both free to air and subscription TV (403). The NRL is experiencing unprecedented popularity with improved TV ratings for Friday night and Sunday afternoon matches and an average crowd attendance of 16,051, an increase of 2.93 % on 2008 figures. In 2009, the Telstra premiership recorded the highest regular season attendance in the history of Rugby League with 3,081,839 people attending the 26 rounds of regular season matches. NRL matches on subscription TV reached more than 3.6 million viewers in 2009, while on average, each regular season round in the NRL reached more than 2.7 million viewers with more than 220,000 listeners tuning into Rugby League on radio every weekend throughout the season (403).

To assist the NRL to remain the centre piece in the free to air and subscription TV schedule, there is a considerable need for a substantial and ongoing commitment to excellence by coaches, sports scientists and strength and conditioning practitioners to advance the knowledge base regarding match preparation, match-play performance and best practice methodologies during the post-match recovery period. Despite the professional status of the NRL as an international sport with a global viewing audience, there remains a lack of research in the key areas of player response to the demands of match-play and the pattern of neuromuscular, endocrine and biochemical recovery in elite Rugby League in comparison to other football codes such as AFL, Rugby Union and Soccer. With the exception of Dr Dan Baker from the Brisbane Broncos, who has set the bench mark for applied strength and power research in professional Rugby League for over 10 years, the majority of research has consisted of retrospective reporting of player anthropometric data, injury rates and comparisons of junior, amateur, and semi-professional player performance characteristics.

The motivation for the present body of work arose from a conversation with Olympic weightlifting coach, Mr Lyn Jones at a Sports Power Coaching accreditation course attended by the author in Brisbane in 2005. During the course of one of many conversations regarding athlete recovery and preparation, Lyn pondered the age-old question of how can a coach determine when an athlete has recovered sufficiently from a workout or competitive performance to enable that athlete to return to training in preparation for subsequent performance? The lack of information pertaining to the physiological demands of Rugby League match-play under current defensive rules, interchange

limitations and the introduction of two on-field referees is evident in any systematic review of the literature. Furthermore a review of the literature revealed no study had examined the neuromuscular, endocrine or biochemical response of elite Rugby League players to competitive match-play. No study has investigated the time course associated with a return to pre-match neuromuscular, endocrine or biochemical measures during the post-match recovery period following NRL match-play.

The present body of work was therefore undertaken to establish the neuromuscular, endocrine, biochemical and physiological demands of match-play in the NRL and to determine the anabolic:catabolic endocrine behaviour, neuromuscular fatigue and muscle damage immediately post-match and for a period of up to 5 days post-match. By determining the time course associated with a return to pre-match hormonal homeostasis and neuromuscular function, the effectiveness of recovery strategies could be established. An increased knowledge base in relation to the neuromuscular, endocrine, biochemical and physiological pattern of response following elite Rugby League match-play may enable a more accurate identification of when players could return to training without interfering with the short term post-match recovery period to be recognised, and preparation for subsequent performance optimised.

## **NAVIGATION OF THE THESIS**

This thesis “by publication” comprises five experimental studies presented as five individual chapters. Each of the five experimental studies are “In press”. All papers are presented in the format accepted for publication and include an introduction, review of the literature, methods, results and discussion sections. Each experiment builds on the previous experiment to increase the knowledge of short-term and long-term post-match physiological, neuromuscular, endocrine, and biochemical responses of elite players as they relate to elite Rugby League match-play.

There are eight Chapters which make up the present thesis. Chapter 1 provides an introduction of the purpose and significance of the research, presents hypothesis associated with each study and outlines the research questions. Chapter 2 provides an overview of the literature with specific reference to the physiological demands and movement patterns associated with Rugby League match-play. The reader is introduced to Global Positioning System (GPS) technology for performance analysis in sports and the validity and reliability of portable GPS units is considered. Chapter 2 also contains a review of neuromuscular fatigue and sports performance with a particular focus on the assessment of movements incorporating the stretch shortening cycle (SSC) to determine neuromuscular fatigue and the role of muscle force, power and the rate of force development in team sports. A review of the literature pertaining to endocrine indices of fatigue, muscle damage and recovery following contact sport concludes Chapter 2.

Chapter 3 is Experimental Study 1, and has been accepted for publication as:

**McLellan, C.P.**, Lovell, D.I., & Gass, G.C. The Role of Rate of Force Development on Vertical Jump Performance. *Journal of Strength and Conditioning Research*, (In Press, 2010).

Chapter 4 is Experimental Study 2, and has been accepted for publication as:

**McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Performance Analysis of Elite Rugby League Match-Play using Global Positioning Systems. *Journal of Strength and Conditioning Research*, (In Press, 2010).

Chapter 5 is Experimental Study 3, and is presented in the format accepted for publication:

**McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Creatine Kinase and Endocrine Responses of Elite Players Pre, During and Post Rugby League Match-Play. *Journal of Strength and Conditioning Research*, 24(11): 2908-2919, 2010.

Chapter 6 is Experimental Study 4, and has been accepted for publication as:

**McLellan, C.P.,** Lovell, D.I., & Gass, G.C. Markers of Post-Match Fatigue in Professional Rugby League Players. *Journal of Strength and Conditioning Research*, (In Press, 2010).

Chapter 7 is Experimental Study 5, and has been accepted for publication as:

**McLellan, C.P.,** Lovell, D.I., & Gass, G.C. Biochemical and Endocrine Responses to Impact and Collision During Elite Rugby League Match-Play. *Journal of Strength and Conditioning Research*, (In Press, 2010).

The *Journal of Strength and Conditioning Research* was specifically selected as the refereed Journal to receive the results of Experiments 1 – 5. It was reasoned that if clinical practice was to improve then the results of Experiments 1 – 5 should be presented in sources that were widely read by Strength and Conditioning and Sports Science practitioners. There was a clear intent that research should inform practice and the *Journal of Strength and Conditioning Research* was therefore the journal of choice.

In addition to the “In press” papers listed in Chapters 3, 4, 5, 6, and 7, the research conducted in completion of the present thesis also contributed to the preparation of the following poster presentations:

**McLellan, C.P.,** Lovell, D.I., & Gass, G.C. Muscle enzyme and endocrine responses of elite players to Rugby League match-play. *Journal of Science and Medicine in Sport*, 12(6) Dec Sup; 106-107, 2009. Presented at the Australian Conference of Science and Medicine in Sport, 14 – 17 October 2009, Brisbane.

Chapter 8 presents the overall discussion and conclusions that summarise the findings of the experimental studies and outlines recommendations for future research to increase our understanding of elite Rugby League match-play.

## **ACKNOWLEDGEMENTS**

I would like to acknowledge a number of people for their support and encouragement throughout the period of my doctoral candidature. Throughout my entire professional career I have received unwavering support from my wife Vanessa and my very understanding children, Ronan and Remi. My family have sacrificed much to allow me to pursue my career and for that words cannot express my gratitude.

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I would also like to acknowledge and thank the Gold Coast Titans NRL Team administration, coaching staff and players, all of whom have been remarkably accommodating during the completion of all research projects that have culminated in the development of the thesis. Sincere thanks also to my friend and tireless assistant at the Gold Coast Titans, Mr Dan Ferris, for his assistance throughout the course of this research.

## **ABSTRACT**

The primary aim of this thesis was to advance our knowledge of the neuromuscular, endocrine, biochemical and physiological responses of elite Rugby League players during competitive match-play. The secondary aim of this thesis was to examine the effects of the short term recovery phase post-match and the associated time-course for a return to hormonal homeostasis, neuromuscular function and musculoskeletal recovery following match-play.

### **Chapter 3 (Experimental Study 1 – Paper 1)**

The purpose of this study was to examine i) the relationship between rate of force development (RFD) and vertical jump (VJ) performance during a counter movement jump ii) the reliability of RFD recorded during the counter movement jump (CMJ) and squat jump (SJ) forms of the VJ. Twenty three physically active men aged  $23 \pm 3.9$  yr participated in the study. Subjects completed three unloaded CMJ and three unloaded SJ in random order on a force plate. RFD was measured during CMJ and SJ movements with vertical jump displacement (VJD) measured simultaneously during the CMJ only. Subjects incorporated arm swing to their CMJ technique to reach up as high as possible and VJD was measured. All SJ were executed with both hands on the hips throughout the full range of movement. Peak rate of force development (PRFD), peak force (PF) and time to peak force (TPF) were significantly correlated to VJD during the CMJ ( $r = 0.68$ ,  $r = 0.51$  and  $r = -0.48$  respectively). The RFD and TPF during the CMJ and SJ were associated with low test re-test reliability (coefficient of variation [CV]: 11.8 – 17.9 %). Peak and average power, PF and VJD produced high test retest reliability (CV: 2.8 – 5.1 %) during both the CMJ and SJ movements. However, caution must be used when interpreting data using PRFD due to low re-test reliability. The results indicate that PRFD, a measure of explosive strength, and PF, a measure of maximal strength are the primary contributors to VJD during the CMJ. Measurement of selected force-time variables during the CMJ and SJ demonstrate acceptable levels of reliability for inclusion in functional assessment protocols to determine the influence of acute or chronic exercise on SSC performance in physically active men.

### **Chapter 4 (Experimental Study 2 – Paper 2)**

The aim of the present study was i) to examine the physiological demands of competitive Rugby League match-play using portable Global Positioning Systems (GPS) to monitor player's movement

patterns and heart rate (HR) and ii) examine positional comparisons to determine if a player's physiological requirements are influenced by their playing position during Rugby League match-play. Twenty two elite male Rugby League players were monitored during five regular season competition matches using portable GPS software. There was no significant difference in the total distance travelled between backs ( $5573 \pm 1128$  m) and forwards ( $4982 \pm 1185$  m) during match-play. Backs and forwards had an average HR of approximately 80 % of their maximum HR ( $162 \pm 11$  and  $165 \pm 12$  b·min<sup>-1</sup> respectively) throughout each match. Backs achieved greater maximum running speed ( $8.6 \pm 0.7$  m·sec<sup>-1</sup>), completed a greater number of sprints ( $18 \pm 6$ ), had less time between sprints ( $3.2 \pm 1.1$  min), achieved a greater total duration of sprinting ( $44.7 \pm 9.1$  s) and covered more distance sprinting ( $321 \pm 74$  m) than forwards ( $6.8 \pm 0.7$  m·sec<sup>-1</sup>,  $11 \pm 5$ ,  $5.2 \pm 2.2$  min,  $25.8 \pm 9.2$  s and  $153 \pm 38$  m respectively). The present study provides insight into the high intensity nature of elite Rugby League competition incorporating real-time accelerometer and GPS technology to establish key performance indicators of match-play. The results identify significant positional differences in total distances covered, running speed profiles and the physiological demands of match-play. Position specific demands on aerobic and anaerobic energy systems during elite Rugby League match-play should be considered when planning post-match recovery protocols and training activities to optimise subsequent performance.

## **Chapter 5 (Experimental Study 3 – Paper 3)**

The purpose of the present study was to i) examine player movement patterns to determine total distance covered during competitive Rugby League match-play using GPS and ii) examine pre, during and post-match plasma creatine kinase (CK) and endocrine responses to competitive Rugby League match-play. Seventeen elite Rugby League players were monitored for a single game. Player movement patterns were recorded using portable GPS units (SPI-Pro, GPSports, Canberra, Australia). Saliva and blood samples were collected 24 hr pre-match, 30 min pre-match, 30 min post-match and then at 24 hr intervals for a period of 5 days post-match to determine plasma CK and salivary testosterone (sTest), cortisol (sCort) and testosterone:cortisol ratio (sT:C). The change in the dependent variables at each sample collection time was compared to 24 hr pre-match measures. Backs and forwards travelled distances  $5747 \pm 1095$  m and  $4774 \pm 1186$  m respectively throughout the match. The sCort and plasma CK increased significantly ( $p < 0.05$ ) from 30 min pre-match to 30 min post-match. Plasma CK increased significantly ( $p < 0.05$ ) post-match, with peak plasma CK concentration measured 24 hr post-match ( $889.25 \pm 238.27$  U.L<sup>-1</sup>). Cortisol displayed a clear pattern of response with significant ( $p < 0.05$ ) elevations up to 24 hr post-match, compared with 24 hr pre-

match. The GPS was able to successfully provide data on player movement patterns during competitive Rugby League match-play. The plasma CK and endocrine profile identified acute muscle damage and a catabolic state associated with Rugby League match-play. A return to normal testosterone:cortisol ratio within 48 hr post-match indicates that a minimum period of 2 days is required for endocrine homeostasis post-competition. Plasma CK remained elevated despite 120 hr of recovery post-match identifying that a prolonged period of at least 5 days of modified activity is required to achieve full recovery following muscle damage during competitive Rugby League match-play. The results support the inclusion of plasma CK and salivary endocrine measures as objective markers of muscle damage and stress experienced by elite Rugby League players pre, during and post-match. Furthermore, the results indicate that plasma CK, sCort, sTest and sT:C ratio are meaningful measures to monitor individual player tolerance to training and competitive loads and should be considered when developing recovery and training plans over the course of an extended season of weekly elite Rugby League competition.

## **Chapter 6 (Experimental Study 4 – Paper 4)**

The aim of the present study was to identify neuromuscular, biochemical and endocrine markers of fatigue following Rugby League match-play. Seventeen elite Rugby League players were monitored for a single match. Peak rate of force development (PRFD), peak power (PP) and peak force (PF) were measured during a countermovement jump (CMJ) on a force plate pre and post match-play. Saliva and blood samples were collected 24 hr pre-match, 30 min pre-match, 30 min post-match and then at 24 hr intervals for a period of 120 hr to determine plasma creatine kinase concentration ([CK]) and salivary cortisol concentration ([sCort]). There were significant ( $p < 0.05$ ) decreases in PRFD and PP up to 24 hr post-match with PF significantly ( $p < 0.05$ ) decreased immediately post-match. The [sCort] significantly ( $p < 0.05$ ) increased from 24 hr pre-match to 30 min pre-match and up to 24 hr post-match compared to 24 hr pre-match. Plasma [CK] significantly ( $p < 0.05$ ) increased 30 min post-match with a peak occurring 24 hr post-match and remained elevated above 24 hr pre-match for at least 120 hr post-match. There were significant ( $p < 0.05$ ) correlations between the increase in plasma [CK] and reduction in PRFD 30 min post-match and 24 hr post-match. The [sCort] was significantly ( $p < 0.05$ ) correlated with the reduction in PF 30 min post-match. Results demonstrate that neuromuscular function is compromised and results in significant impairment of PRFD, PF and PP for up to 48 hr following elite Rugby League match-play. Elevated plasma [CK] despite 120 hr recovery indicates that damage to muscle tissue following Rugby League match-play may persist for at least five days post-match. Despite the prolonged presence of elevated plasma [CK] post-match, strength

training 48 hr post-match may have resulted in a compensatory increase in PRFD supporting the inclusion of strength training during the short-term post-match recovery period. The CMJ offers a functional analysis measure of neuromuscular fatigue and exercise induced muscle damage and should be considered to establish a comprehensive profile of individual adaptation and recovery following elite Rugby League match-play.

## **Chapter 7 (Experimental Study 5 – Paper 5)**

The purpose of the present study was to investigate the relationship between the pre-match and short term post-match biochemical and endocrine responses to the intensity, number and distribution of impact forces associated with collisions during elite Rugby League match-play. Seventeen elite male Rugby League players each provided blood and saliva samples 24 hr pre-match, 30 min pre-match, 30 min post-match and then at 24 hr intervals for a period of 5 days post-match to determine plasma creatine kinase concentration ([CK]) and salivary cortisol concentration ([sCort]). The intensity, number and distribution of impact forces experienced by players during match-play were recorded using portable Global Positioning Systems (GPS) and integrated accelerometer. The change in the dependent variables at each sample collection time was compared to 24 hr pre-match and 30 min pre-match measures. Plasma [CK] and [sCort] increased significantly ( $p < 0.05$ ) during match-play. Significant correlations ( $p < 0.05$ ) were observed between the number of hit-ups and peak plasma [CK] 24 hr post match, 48 hr post-match and 72 hr post-match ( $p < 0.05$ ). The number of impacts recorded in Zone 5 (8.1 – 10.0 G) and Zone 6 (> 10.1 G) during match-play were significantly correlated ( $p < 0.05$ ) to plasma [CK] 30 min post-match, 24 hr post, 48 hr post and 72 hr post-match. The GPS and integrated accelerometer was able to provide data on the intensity, number and distribution of impacts resulting from collisions during match-play. Elite Rugby League match-play resulted in significant skeletal muscle damage, and was highly dependent on the number of heavy collisions > 8.1G. Plasma [CK] remained elevated 120 hr post-match identifying that at least five days of modified activity is required to achieve full recovery following elite Rugby League match-play. A gradual reduction in plasma [CK] during the five day post-match recovery phase coincided with reduced training loads and no additional physical trauma indicting plasma [CK] can be used to monitor acute recovery from elite Rugby League match-play.

## **LIST OF PUBLICATIONS**

1. **McLellan, C.P.**, Lovell, D.I., & Gass, G.C. The Role of Rate of Force Development on Vertical Jump Performance. *Journal of Strength and Conditioning Research*, In Press, 2010.
2. **McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Performance Analysis of Elite Rugby League Match-Play using Global Positioning Systems. *Journal of Strength and Conditioning Research*, In Press, 2010.
3. **McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Creatine Kinase and Endocrine Responses of Elite Players Pre, During and Post Rugby League Match-Play. *Journal of Strength and Conditioning Research*, 24(11): 2908-2919, 2010.
4. **McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Markers of Post-Match Fatigue in Professional Rugby League Players. *Journal of Strength and Conditioning Research*, In Press, 2010.
5. **McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Biochemical and Endocrine Responses to Impact and Collision During Elite Rugby League Match-Play. *Journal of Strength and Conditioning Research*, In Press, 2010.

## **LIST OF CONFERENCE PROCEEDINGS**

1. **McLellan, C.P.**, Lovell, D.I., & Gass, G.C. Muscle enzyme and endocrine responses of elite players to Rugby League match-play. *Journal of Science and Medicine in Sport*, 12(6) Dec Sup; 106-107, 2009. Presented at the Australian Conference of Science and Medicine in Sport, 14 – 17 October 2009, Brisbane.

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## **LIST OF SYMBOLS AND ABBREVIATIONS**

Dot [ · ]	above any symbol indicates a time derivative
Dash [ - ]	above any symbol indicates a mean value

### **SYMBOLS**

$\alpha$	alpha
$\beta$	beta
r	Pearsons product moment correlation coefficient
p	statistical significance
$\mu$	micro
$^{\circ}\text{C}$	temperature in degrees celsius
$\pm$	plus or minus
%	percent
>	greater than
<	less than

### **UNITS OF MEASUREMENT**

ANOVA	analysis of variance
b $\cdot$ min <sup>-1</sup>	beats per minute
cm	centimetres
CV	coefficient of variation
ES	effect size
ft	feet
g	grams
G	gravitational force
hr	hours
hr $\cdot$ wk <sup>-1</sup>	hours per week
HR	heart rate
HR <sub>max</sub>	maximum heart rate
Hz	Hertz
HSD	Tukey's honestly significant difference

ICC	intraclass correlation coefficient
kg	kilogram
km·hr <sup>-1</sup>	kilometres per hour
km·wk <sup>-1</sup>	kilometres per week
m	metres
min	minutes
m·min <sup>-1</sup>	metres per minute
mm	millimetre
ms	millisecond
m.sec <sup>-1</sup>	metres per second
ms <sup>2</sup>	metres per second squared
N	Newton
ng·mL <sup>-1</sup>	nanogram per millilitre
nm·L <sup>-1</sup>	nanomole per litre
N·s <sup>-1</sup>	Newton per second
pg·mL <sup>-1</sup>	picograms per millilitre
rpm	revolutions per minute
s	seconds
SD	standard deviation
SEE	standard error of estimate
SEM	standard error of mean
TE	typical error
VO <sub>2</sub> max	maximum oxygen uptake
U·L <sup>-1</sup>	units per litre
W	Watts
wk	week
yr	years
µg.dL <sup>-1</sup>	micro-gram per decilitre
µL	micro litre

## ENZYMES / METABOLITES

ACTH	adrenocorticotrophic hormone
ADP	adenosine diphosphate
ATP	adenosine triphosphate
Ca <sup>2+</sup>	calcium
CGB	cortisol binding globulin
CK	creatine kinase
[CK]	creatine kinase concentration
CK-BB	brain creatine kinase isoform
CK-MB	cardiac muscle creatine kinase isoform
CK-MM	skeletal muscle creatine kinase isoform
[Cort]	cortisol concentration
FSH	follicle stimulating hormone
GOT	glutamic oxaloacetic transaminase
H <sup>+</sup>	hydrogen ion
K <sup>+</sup>	potassium
LDH	lactate dehydrogenase
LH	leutenising hormone
Na <sup>+</sup>	sodium
NH <sup>3</sup>	ammonia
PCr	phosphocreatine
Pi	inorganic phosphate
sCort	salivary cortisol
[sCort]	salivary cortisol concentration
SHBG	sex hormone binding globulin
sT:C	salivary testosterone:cortisol ratio
sTest	salivary testosterone
[sTest]	salivary testosterone concentration
T:C	testosterone:cortisol ratio

## VARIABLES AND ABBREVIATED TERMS

1RM	one repetition maximum
AFL	Australian Football League
ARFD	average rate of force development
AF	average force
AP	average power
BT	bench throw
BUHREC	Bond University Human Research Ethics Committee
CHO	carbohydrate
CMJ	countermovement jump
CNS	central nervous system
CWI	cold water immersion
DJ	drop jump
DOMS	delayed onset muscle soreness
DWR	deep water running
EE	elbow extensors / elbow extension
EF	elbow flexors / elbow flexion
e.g.	example
EIMD	exercise induced muscle damage
EMG	electromyography
EMS	electromyostimulation
ES	electrical stimulation
F	force
FTV	force-time variable
GCT	ground contact time
GPS	global positioning system
GRF	ground reaction force
HFF	high frequency fatigue
HPA	hypothalamic-pituitary axis
H-reflex	hoffman reflex
KE	knee extension / knee extensor
KF	knee flexion / knee flexor
KPI's	key performance indicators
LIST	Loughborough Intermittent Shuttle Test
LFF	low frequency fatigue
MARP	Maximal anaerobic running power

MHC	myosin heavy chain
MIVC	maximum isometric contraction
MMG	mechanomyography
MN	motor neuron
MPF	mean power frequency
MRFD	maximum rate of force development
M-wave	skeletal muscle action potential
MU	motor unit
MVC	maximum voluntary contraction
n	number of subjects
NCAA	National Collegiate Athletic Association (USA)
NM	neuromuscular
NPC	National Provincial Championship (New Zealand Rugby Union)
NRL	National Rugby League
NSWPL	New South Wales Premier League
P	power
PF	peak force
PP	peak power
RFD	rate of force development
PRFD	peak rate of force development
RBE	repeated bout effect
Reps	repetitions
RIA	radioimmunoassay
RM	repetition maximum
ROM	range of movement
RSA	repeated sprint ability
RSAT	repeated sprint ability test
RT	resistance training
SA	selective availability
SJ	squat jump
SR	sarcoplasmic reticulum
SSC	stretch shortening cycle
SPSS	statistical package for the social sciences
T1	first thoracic vertebrae
TMA	time motion analysis
TMS	transcranial magnetic stimulation

TPF	time to peak force
T-tubule	transverse tubule
TV	television
US	United States
USA	United States of America
USG	urine specific gravity
UV	ultraviolet
VA	voluntary activation
VJ	vertical jump
VJD	vertical jump displacement
VL	vastus lateralis
VM	vastus medialis
WiFi	wireless fidelity

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