

**EFFECTS OF TAPERING ON POWER-FORCE-VELOCITY PROFILING AND
PERFORMANCE IN ELITE RUGBY LEAGUE**

James de Lacey

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requirements for the degree of Masters of Sport and Exercise

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

A handwritten signature in black ink, appearing to read 'James de Lacey', written in a cursive style.

James de Lacey

April 26th 2014

LIST OF PUBLICATIONS FROM THESIS

de Lacey, J., Brughelli, M., McGuigan, M. R., Hansen, K. Strength, Speed and Power Characteristics of Elite Rugby League Players. *Journal of Strength and Conditioning Research*. Feb 10. [Epub ahead of print]

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Chapter 2. Tapering for Resistance Training in Team Sports (in review AJSC)	de Lacey 85% Brughelli 7.5% McGuigan 2.5% Hansen 2.5%
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Chapter 4. The Effects of Tapering on Power-Force-Velocity Profiling and Jump Performance in Professional Rugby League Players (in review JSCR)	de Lacey 85% Brughelli 7.5% McGuigan 2.5% Hansen 2.5%



James de Lacey



Matt Brughelli



Michael McGuigan



Keir Hansen

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ETHICS APPROVAL

Ethical approval for this research was granted by the Auckland University of Technology Ethics Committee (AUTEC). The AUTEC reference was 12/95, with approval granted originally on 2nd December 2013

ABSTRACT

Rugby league is a high intensity, collision sport where understanding strength, speed and power characteristics are imperative for strength and conditioning coaches to recognise the demands of the sport. Due to the high demands of elite rugby league, fatigue can impair on field performance. Implementing a taper can aid in reducing the effect of fatigue on performance. This thesis sought to gain insight into strength, speed and power differences between forwards and backs, tapering and physiological and performance changes and the effects of tapering on power-force-velocity profiling and jump performance in professional rugby league players. Our findings showed that backs are faster over 10 m (Effect Size=1.26) and 40 m (ES=1.61) than forwards. Furthermore, backs produce greater relative horizontal force (ES=0.87) and power (ES=1.04) compared to forwards. Our findings suggest that developing horizontal force and power may potentially improve short sprint performance in rugby league players. On the basis of the literature review, significant improvements in physiological and performance measures occurred after a short tapering period. In the fourth chapter, a 21 day step taper was implemented leading into the in-season with 7 professional rugby league players. Measurements included vertical jump, performance and force-velocity-power variables. Our findings show positive changes in the power-force-velocity profile when implementing a step taper. A likely increase in F_0 and a very likely increase in P_{max} was found after a 21 day tapering period. Furthermore, jumping performance saw likely to most likely increases post taper. We suggest implementing a short step taper leading into the season where resistance training volume decreases to improve P_{max} and jump performance.

CHAPTER 1: INTRODUCTION AND RATIONALE

Background

Rugby league is an intermittent collision sport that involves frequent bouts of high-intensity activity (e.g. sprinting, tackling and wrestling) with short bouts of low-intensity activity (e.g. walking and jogging) (22, 28, 34, 50, 51, 53). Forwards and backs are likely to perform 11.1 ± 5.1 and 18.7 ± 6.2 sprints per match covering a total distance of 153 ± 38 m and 321 ± 74 m respectively (34). Forwards generally display greater strength than backs while backs generally sprint faster and jump higher than their forward counterparts (10, 29, 36). Previous research comparing forwards and backs in rugby league has not explained how backs are better sprinters and jumpers even though they have lower maximal strength than forwards. The high intensity nature of rugby league creates great physical and physiological demands which are increased through large numbers of physical collisions throughout a game (22). However, these demands can subsequently result in fatigue from week to week impairing on field performance (18, 19). Fatigue has been shown to result in a reduction in tackling technique (18). Furthermore, Gabbett et al. (19) found significant associations between; vertical jump and the ability to beat a player, 20-40m sprint and the ability to beat a player, play the ball speed and offloading. Therefore, a reduction in these performance variables due to fatigue can hinder low and high speed movements as well as tackling proficiency (28).

One way to reduce fatigue and improve strength, speed and power is through implementing a taper. A taper is a reduction in training load over a period of time with the aim to reduce the physiological and psychological stress of daily training and optimise sports performance (4, 39, 43, 54). Previous research has shown positive changes in physiological and performance measures after a tapering period (12, 14, 23, 26). Testosterone:cortisol (T:C) ratio has been shown to significantly increase and creatine kinase (CK) to significantly decrease after a 14 day training cessation (26). CK has also been seen to decrease after a 7 day taper (12). Vertical jump, short sprint speed and isokinetic strength are performance variables that have shown positive improvements with tapering (12, 14, 23). However, there is very little research on tapering and the effect on the force-velocity profile and maximal power (Pmax).

The force-velocity (F-v) mechanical capabilities of the neuromuscular system are well described by the inverse force-velocity and parabolic power-velocity relationships when multi joint movement are considered (44). To date, only one study has looked at the effect of tapering on the force-velocity profile but was done in the sedentary population (2). The

authors found a significant increase in the magnitude of force produced at all velocities, especially at velocities greater than the pre taper values after three months of detraining in untrained subjects. Furthermore, the authors found a significant increase in the magnitude of power produced at all velocities and especially at velocities greater than the pre taper values. Also, significant increases in peak velocity, peak rate of force development and angular acceleration were observed post detraining compared to pre detraining (2).

There is currently no research to date investigating the effect of tapering on the power-force-velocity profile in team sports. It is thought that a taper may shift the power-force-velocity profile further towards velocity capabilities and in turn, improving maximal power.

Purpose Statement

The purpose of this thesis is to provide greater knowledge in regards to performance characteristics and tapering of resistance training in elite rugby league. Firstly, literature examining the effects of tapering on physiological and performance variables will be reviewed. Furthermore, specific guidelines will be suggested for tapering resistance training in team sports. Secondly, a comparison of strength, speed and power characteristics between rugby league forwards and backs will be investigated including horizontal force, power and isokinetic strength. Thirdly, the effects of tapering specifically on the power-force-velocity profile and performance will be investigated. Practical recommendations will be provided based on the research on implementing a taper and improving performance.

Study aims

The aims of this research were as follows:

1. To review published literature on tapering in all sports and populations, specifically looking at tapering in team sports and rugby.
2. To examine the positional differences in strength, speed and power characteristics of elite rugby league players, including; sprint performance, sprint kinetics and kinematics and isokinetic strength.

3. To investigate the effects of tapering on the force/velocity profile and performance in elite rugby league players.
4. To synthesise the data collected in the review and subsequent studies to provide a greater understanding for strength and conditioning coaches to guide the way they plan their training and season.

Study limitations

1. Participants were not running over ground for sprinting in Chapter 2. Furthermore, force could not be measured from same location on the Woodway treadmill.
2. No control group and a small sample size were used in Chapter 4.
3. Testing was only performed once pre taper and once post taper in Chapter 4.

Study delimitations

1. Participation in the study was limited to participants that were part of the Warriors National Rugby League wider training squad. This was to ensure participants would be considered elite athletes.

Structure of the Thesis

This thesis consists of 5 chapters which includes both original research and reviews at different stages of publication. Each chapter is therefore presented in the journal format and wording it was intended for. References are included as an overall reference list of the entire thesis at the end of the thesis. The structure of this thesis is shown in a flow chart in Figure 1.

The second chapter contains a review of the literature relating to tapering of resistance training in team sports. This review covers the physiological and performance changes that occur after a tapering period. Furthermore, recommendations are made specifically for tapering resistance training for team sports.

The third chapter includes the accepted paper from the Journal of Strength and Conditioning Research, where a comparison of strength, speed and power characteristics were compared between forwards and backs in elite rugby league.

The fourth chapter consists of a pre-post intervention study looking at the effects of tapering on the power-force-velocity profile in professional rugby league.

The fifth and final chapter comprises an overall discussion of the findings from the presented research as well as practical recommendations and future considerations.

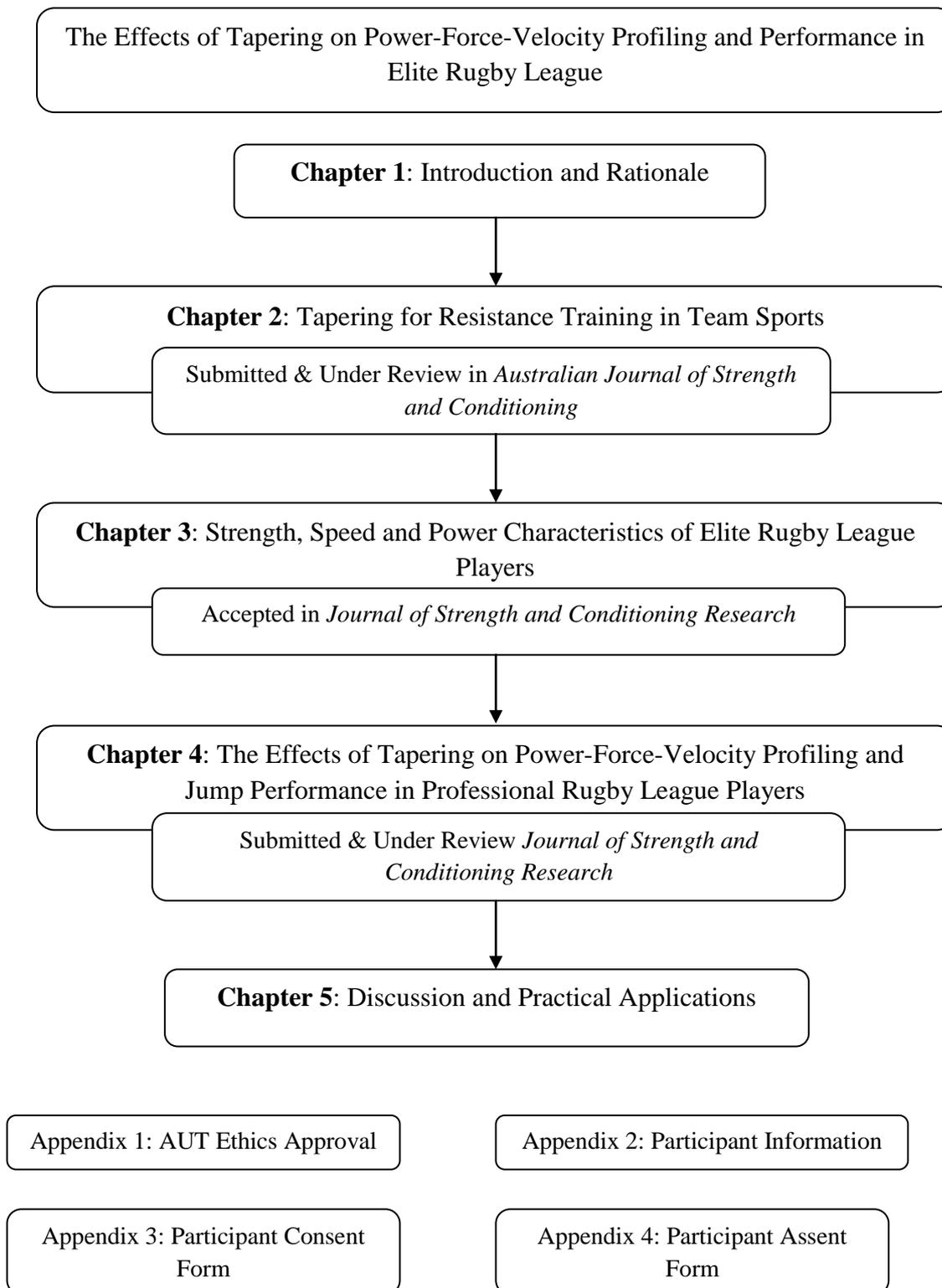


Figure 1: Overview of master's thesis chapter flow.

CHAPTER 2: TAPERING FOR RESISTANCE TRAINING IN TEAM SPORTS

ABSTRACT

A taper is a reduction in training load over a period of time that allows an athlete to recover from the stress of training. In doing so, physiological and performance benefits can be enhanced following a tapering period. A taper can be manipulated through alterations in intensity, volume and duration. Unfortunately, there is a paucity of literature on tapering in team sports that require high levels of performance for extended in-seasons. The purpose of this article is to review the physiological and performance adaptations that occur after a taper, and provide a practical guide for tapering in team sports

INTRODUCTION

A taper is a reduction in training load over a period of time with the aim to reduce the physiological and psychological stress of daily training and optimise sports performance. The taper should be scheduled in the weeks immediately prior to a competition (39, 43, 54). The taper is achieved through manipulating training intensity, volume, duration, frequency and mode, and can be implemented through a variety of paradigms (for example, progressive or step). Reducing the training load runs a risk of detraining but high intensity training during the taper may reduce this risk and can possibly induce positive performance adaptations. Reducing the training volume during the taper may not negatively affect the athlete but can potentially improve performance after the taper. The optimal taper for team collision sports which reduces physiological stress markers as well as improving performance is unknown. Bosquet et al. (2) suggest an optimal taper may exist where the training volume is decreased by 41-60% eliciting performance gains after a 2 week taper. According to Pyne et al. (43) a worthwhile improvement in mean power in elite athletes is 0.5-3.0% from sprint to endurance events in individual sports such as running, cycling and swimming. However, the reviews by Bosquet et al. (2) and Pyne et al. (43) only included individual endurance sports such as swimming, cycling, running and rowing. Different protocols are needed for team sports involving muscle trauma resulting from multiple physical contacts/collisions as extra recovery may be required. Hence, this review will examine different tapering protocols and will offer a practical guide/example for tapering in team sports.

Physiological Changes Associated With The Taper

Both testosterone:cortisol ratio (T:C) and creatine kinase (CK) have been suggested to be markers of training stress and are influenced by fitness level, and the duration, intensity and mode of exercise (12, 15, 16, 27, 30, 40). Hortobagyi et al. (26) implemented a taper involving a full cessation of exercise during their study of a 14 day tapering intervention and reported a significant increase in T:C of 67.6% (see Table 1). Other studies have not shown significant changes in T:C and using progressive or step reduction tapers ranging from six days to four weeks (12, 40-42). A progressive taper involves a gradual decrease in training load while a step taper involves a sudden reduction in training load for the duration of the taper (43). The complete cessation of exercise utilised by Hortobagyi et al. (26) may have triggered a response resulting in the increase in T:C which is accepted to indicate anabolic

processes. It is possible the increase in T:C ratio is a result of the body minimizing the catabolic processes initiated from detraining (26). The continuation of training throughout the taper employed by the remaining studies in table 1 may not have allowed the body to initiate this anti-catabolic response as it was not needed and therefore, T:C would remain unchanged.

Table 1. Testosterone:Cortisol Ratio Pre and Post Taper

Study (Year)	Type of Athletes	Taper Duration (days)	Testosterone:Cortisol Ratio (mean \pm SD)		%Change	Effect Size
			Pre Taper	Post Taper		
Hortobagyi et al. (26)	4 Powerlifters & 8 former Div 1 American Football Players	14 day cessation of exercise	0.37 \pm 0.13	0.62 \pm 0.22*	67.60%	1.92
Mujika et al. (40)	Eight highly trained national and international level male swimmers	Progressive 4 week taper	0.028 \pm 0.008	0.024 \pm 0.006	14.30%	0.50
Mujika et al. (41)	8 well trained male middle-distance runners	6 day medium or low volume taper	0.37 \pm 0.14	0.40 \pm 0.13	8.10%	0.21
Mujika et al. (42)	10 well-trained male middle-distance runners	6 day high frequency (HFT) or moderate frequency taper (MFT)	HFT = 0.37 \pm 0.04 MFT = 0.29 \pm 0.06	HFT = 0.42 \pm 0.15 MFT = 0.35 \pm 0.08	HFT = 13.5% MFT = 20.7%	HFT = 1.25 MFT = 1.00
Coutts et al. (12)	7 Rugby League Players	Step reduction over 7 days reducing training time by 55% and intensity by 17.4%	22.11 \pm 5.4	23.9 \pm 3.1	8.10%	0.33

*significantly different to pre taper (p<0.05)

Decreases in CK have been noted post taper in subjects ranging from endurance to power athletes. Coutts et al. (12) and Hortobagyi et al. (26) observed significant decreases in CK post taper of 62.5% and 82.3% respectively compared to pre taper values (see Table 2). Similarly, three other studies found decreases in CK post taper compared to pre taper but these decreases were not statistically significant (9, 40, 42). The conflicting changes in CK may have been influenced by subject characteristics. For example, Coutts et al. (12) and Hortobagyi et al. (26) showed a significant decrease in CK post taper which may have been due to their subjects being involved in sports that cause high muscle trauma (American football, powerlifting and rugby league) compared to the endurance sports of running and swimming (33, 48, 49, 52). The pre taper CK concentrations in these subjects were significantly greater because of this high muscle trauma and therefore allowed a greater potential for change compared to the other four studies that used endurance athletes. It seems from the studies in table 2 that the tapering protocol does not have a great effect on changes in CK, unlike T:C where changes seem to be influenced by the amount of training throughout a taper.

Table 2. CK Levels Pre and Post Taper

Study (Year)	Type of Athletes	Taper Duration (days)	Creatine Kinase (IU·l ⁻¹)		%Change	Effect Size
			Pre Taper	Post Taper		
Hortobagyi et al. (26)	4 Powerlifters & 8 former Div 1 American Football Players	14 day cessation of exercise	854.3 ± 296.61	151.5 ± 25.41*	82.3	2.4
Mujika et al. (40)	Eight highly trained national and international level male swimmers	Progressive 4 week taper	155.3 ± 62.1	119.0 ± 38.0	23.4	0.58
Child et al. (9)	Two matched groups of seven male runners	6 day progressive taper reducing volume by 85%	115 ± 24	108 ± 24	6.1	0.29
Mujika et al. (41)	8 well trained male middle-distance runners	6 day medium or low volume taper	102.6 ± 63.7	113.4 ± 108.8	10.5	0.17
Mujika et al. (42)	10 well-trained male middle-distance runners	6 day high frequency (HFT) or moderate frequency taper (MFT)	HFT = 154.0 ± 77.5 MFT = 109.5 ± 87.0	HFT = 145.8 ± 96.8 MFT = 53.3 ± 11.6	HFT = 5.3 MFT = 51.3	HFT = 0.11 MFT = 0.65
Coutts et al. (12)	7 Rugby League Players	Step reduction over 7 days reducing training time by 55% and intensity by 17.4%	1329 ± 1003	498 ± 402*	62.5	0.83

*significantly different to pre taper (p<0.05)

Performance Variables

Performance measures such as vertical jump, 10-40 m sprint times and isoinertial strength provide important measures of an athlete's progress and athletic ability (3, 14, 17). Changes in 10-40 m sprint times and vertical jump from pre to post taper have exhibited very similar improvements. The research suggests there is a trend for jumping distance to increase and sprint times to decrease (12, 14, 26) (see Table 3).

Coutts et al. (12) showed a significant 2.1% decrease in 10m sprint time and a non significant decrease in 40 m sprint time of 0.37% post taper compared to pre taper times. Similar to this, Elloumi et al. (14) reported significant decreases in sprint times over 10, 20 and 30m distances post taper of 3.2%, 2.2% and 2.5% respectively compared to pre taper times (Table 3). Coutts et al. (12) also observed an improvement in jumping performance with vertical jump increasing significantly post taper by 5.1% compared to pre taper. Furthermore, Hortobagyi et al. (26) measured vertical jump height through pre and post taper but found no significant changes in jump height (Table 4). The similarities in the improvements of jumping and sprinting may have occurred due to the characteristics of the subjects used. The subjects involved in Coutts et al. (12); Elloumi et al. (14) and Hortobagyi et al. (26) were involved in collision sports or a sport that causes a high level of muscle trauma and competed at a high level in their chosen sport. The tapering period may have provided the athletes with adequate recovery. This has been shown in tables 1 and 2 where significant improvements in physiological measures were observed by Coutts et al. (12) and Hortobagyi et al. (26). Both these studies utilised power and collision sport athletes, which suggests adequate recovery as CK and T:C are markers of training stress.

Furthermore, improvements in performance may be related to changes in muscle fibre properties. Andersen et al., (1, 2) found maximal unloaded movement speed and power increased significantly after a tapering period. This was due to an increase in the proportion of fast myosin heavy chains (MHC) and a shift towards faster MHC phenotypes (fast twitch type IIA to fast twitch type IIX) that occurred over the tapering period. Type IIX muscle fibres contract approximately twice as fast as type IIA fibres which may help to explain the performance improvements of the jumping and sprinting as these are very high velocity movements that involve fast twitch muscle fibres (5, 31).

Table 3. Sprint Times and Vertical Jump Height Pre and Post Taper

Study (Year)	Type of Athletes	Taper Duration (days)	Sprint Times (s) & VJ (cm)		%Change	Effect Size
			Pre Taper	Post Taper		
Hortobagyi et al. (26)	4 Powerlifters & 8 former Div 1 American Football Players	14 day cessation of exercise	VJ = 52.1 ± 8.3	VJ = 53.8 ± 8.7	VJ = 3.30%	VJ = 0.2
Coutts et al. (12)	7 Rugby League Players	Step reduction over 7 days reducing training time by 55% and intensity by 17.4%	10 m = 1.92 ± 0.11 40 m = 5.46 ± 0.20 VJ = 59.4 ± 9.6	10 m = 1.88 ± 0.10* 40 m = 5.44 ± 0.19 VJ = 62.4 ± 9.9*	10 m = 2.1%* 40 m = 0.37% VJ = 5.1%*	10 m = 0.36 40 m = 0.1 VJ = 0.31
Elloumi et al. (14)	16 Elite Rugby 7s players	Progressive 2 week taper with duration and intensity gradually declining	10 m = 1.86 ± 0.06 20 m = 3.16 ± 0.08 30 m = 4.39 ± 0.13	10 m = 1.80 ± 0.07* 20 m = 3.09 ± 0.07* 30 m = 4.28 ± 0.12*	10 m = 3.2%* 20 m = 2.2% 30 m = 2.5%*	10 m = 1 20 m = 0.88 30 m = 0.85

*significantly different to pre taper (p<0.05) VJ=vertical jump

Table 4. Isoinertial and Isokinetic Strength Pre and Post Taper

Study (Year)	Type of Athletes	Taper Duration (days)	Isoinertial (kg) & Isokinetic Strength (N.m)		%Change	Effect Size
			Pre Taper	Post Taper		
Hortobagyi et al. (26)	4 Powerlifters & 8 former Div 1 American Football Players	14 day cessation of exercise	BP 1RM = 134.1 ± 19.5	BP 1RM = 131.1 ± 18.4	BP 1RM = 2.24%	BP 1RM = 0.15
			SQ 1RM = 192.2 ± 31.8	SQ 1RM = 190.5 ± 29.0	SQ 1RM = 0.88%	SQ 1RM = 0.05
			Quad ISKs = 844 ± 321	Quad ISKs = 717 ± 223	Quad ISKs = 15.05%	Quad ISKs = 0.40
			Quad ISKf = 947 ± 303	Quad ISKf = 853 ± 358	Quad ISKf = 9.93%	Quad ISKf = 0.31
Coutts et al. (12)	7 Rugby League Players	Step reduction over 7 days reducing training time by 55% and intensity by 17.4%	SQ 3RM = 133.9 ± 18.2	SQ 3RM = 143.6 ± 24.8*	SQ 3RM = 7.24%*	SQ 3RM = 0.53
			BP 3RM = 109.3 ± 17.9	BP 3RM = 115 ± 17.3*	BP 3RM = 41.81%*	BP 3RM = 0.32
			Quad ISKs = 164.5 ± 19.5	Quad ISKs = 239.5 ± 38.2*	Quad ISKs = 45.59%*	Quad ISKs = 3.85
			Ham ISKs = 117.3 ± 20.4	Ham ISKs = 135.6 ± 16.2*	Ham ISKs = 15.60%*	Ham ISKs = 0.90
			Quad ISKf = 162.8 ± 15	Quad ISKf = 176.2 ± 28.7	Quad ISKf = 8.23%	Quad ISKf = 0.89
			Ham ISKf = 108.4 ± 13.6	Ham ISKf = 128.1 ± 22.3*	Ham ISKf = 18.17%*	Ham ISKf = 1.45
Garcia-Pallares et al. (23)	14 elite flat water kayakers	4 week taper before competition then 5 weeks training cessation (TC) or reduced training (RT)	BP 1RM (TC) = 137	BP 1RM (TC) = 125*	BP 1RM (TC) = 8.76%*	BP 1RM (TC) = 1.81
			PBP 1RM (TC) = 131	PBP 1RM (TC) = 121*	PBP 1RM (TC) = 7.63%*	PBP 1RM (TC) = 1.98
			BP 1RM (RT) = 138	BP 1RM (RT) = 133	BP 1RM (RT) = 3.62%	BP 1RM (RT) = 0.67
			PBP 1RM (RT) = 133	PBP 1RM (RT) = 130	PBP 1RM (RT) = 2.26%	PBP 1RM (RT) = 0.87

*significantly different to pre taper (p<0.05) BP=bench press, SQ=squat, 1RM=1 repetition maximum, 3RM=3 repetition maximum, TC=training cessation, RT=reduced training, ISKs=isokinetic slow, ISKf=isokinetic fast

Conflicting findings have been observed in isoinertial strength from pre to post taper (see Table 4). Coutts et al. (12) reported changes in isoinertial strength from pre to post taper with a significant increase in 3RM squat and bench press (7.2% and 5.2% respectively). In contrast to this, Garcia-Pallares et al. (23) observed significant decreases of 8.9% and 7.8% in bench press and bench pull 1 repetition maximum isoinertial strength, respectively, for post taper compared to pre taper measures in the training cessation group. The reduced training group showed no significant changes in these strength measures (Table 4). While no significant changes were found by Hortobagyi et al. (26) a trending decrease in both the bench press and squat were observed post taper compared to pre taper (see Table 4).

The decrease in isoinertial strength in the studies by Garcia-Pallares et al., (23) and Hortobagyi et al., (26) may have occurred due to their tapering protocols. Both of these studies employed a complete cessation from exercise which may have led to a detraining effect on isoinertial strength in the athletes. The non significant decrease in isoinertial strength observed by Garcia-Pallares et al. (23) may not have reached statistical significance due to training still being undertaken through the tapering intervention. However, after competition, the subjects in the reduced training group performed only one resistance training session and two endurance training sessions a week for five weeks thus possibly preventing big decreases in strength. In addition to this, Hortobagyi et al. (26) may not have used a tapering intervention long enough to induce significant decreases in isoinertial strength in their subjects, which Garcia-Pallares et al. (23) demonstrated in their training cessation group.

The difference in results between Coutts et al. (12) and Garcia-Pallares et al. (23) may have been due to the extended tapering duration that the athletes in the Garcia-Pallares et al. (23) study went through. The authors tapered for 4 weeks before competition and utilised a further taper after competition. This meant training volume was very low. During the first four weeks of tapering, only two strength training sessions were undertaken a week and after competition, one strength training session a week was performed for five weeks or a complete training cessation occurred. Furthermore, 5-10 endurance training sessions were performed during the first four week taper and two endurance sessions during the post competition five week taper. This could explain why decreases in strength were seen as endurance training was the primary focus through the tapering intervention. Coutts et al. (12) on the other hand only tapered for seven days but still resumed training with a large decrease of 55% in training time and a slight decrease of 17.4% in training intensity. This may have allowed the athletes in that study to recover from a strenuous training period while still

training twice over the 7 days. Also 7 days of tapering may not be long enough to see any decrease in the performance measures.

The literature presented in Table 3 suggest high velocity movements such as sprinting and jumping respond optimally to a tapering period of 7 to 14 days where training load and intensity is reduced rather than implementing a complete cessation of exercise. Furthermore, Table 4 suggests isoinertial strength can either decrease or increase over the tapering period and may depend on the duration of taper and training modalities undertaken during the taper. Strength training needs to be a priority during a short tapering period in order to prevent significant decreases in isoinertial strength.

Force/Velocity Relationship

The force/velocity relationship is the relationship in which the slope may indicate the importance of force and velocity to determine the optimal power output for each individual (38). This relationship has been shown to influence ballistic performance of the lower limb neuromuscular system (44, 47). Increasing the ability to develop high levels of force at low velocities or low levels of force at high velocities may improve power output (11, 13, 47). Thus, potentially influencing the ability to accelerate a mass as much as possible in the shortest time possible (44). For a given maximal power output, an unfavourable balance between force and velocity can lead to a 30% decrease in performance (44, 47). To date, only one study to date has investigated the force/velocity relationship pre and post taper (2). Andersen et al. (2) found a significant increase in the magnitude of force produced at all velocities, especially at velocities greater than the pre taper values after three months of detraining in untrained subjects. Furthermore, the authors found a significant increase in the magnitude of power produced at all velocities and especially at velocities greater than the pre taper values. Also, significant increases in peak velocity, peak rate of force development and angular acceleration were observed post detraining compared to pre detraining.

As compound movements such as squat jumps emulate sporting movements closer than isolation movements, changes in the force/velocity profile measured through compound movements may be a better predictor of sporting performance. Furthermore, Andersen et al. (2) used sedentary subjects in their study and used a three month detraining period. During a professional athletes season, an athlete would not be able to give up three months of training and Coutts et al. (12) has shown positive changes in performance and physiological stress markers when a reduced training load is implemented for seven days. The results Andersen et

al. (2) reported may differ significantly in a professional team sport setting, due to the type of subjects and the tapering protocol that the authors used compared to a more functional taper. Furthermore, no performance tests were used and thus it is difficult to extrapolate this data into a performance or sporting setting.

Recent advances in technology have allowed for field assessment of force-velocity and power profiles during sprinting and jumping (38, 44, 47). Future research should consider assessing individual force-velocity profiles pre- and post- tapering.

PRACTICAL APPLICATIONS FOR TEAM SPORTS

The effect of tapering on physiological and performance variables in team sports has been reported previously (12, 14, 26). According to the literature, a tapering period between 7-14 days seems to be ideal to elicit positive changes in performance and physiological measures. A step reduction taper seems to be the most effective with short tapering periods (14 days or less). The longer the tapering period, the slower the reduction in volume should be (i.e. progressive taper) (54). During the taper, resistance training intensity should be maintained or increased while volume should decrease compared to pre taper programming. An example guide has been presented in tables 5 and 6. Conditioning work could be done as planned so aerobic and anaerobic systems can be improved or maintained during this time. The taper has been suggested to be implemented in the weeks prior to competition (43, 54). However, the taper can be used in additional scenarios that may benefit the athlete and team as tapering periods can be as short as 7 days. These could be at the end of a preseason, before the playoffs, during bye weeks and identifying athletes that are in need of a taper by monitoring fatigue and performance.

A timeline of how the taper could be implemented is presented in Figure 2. In this example, a total of 16 weeks is allocated to the preseason. During the strength/hypertrophy phase, intensity is relatively low (60-80% 1RM) while volume (573 reps/week) is much higher than the other two phases. The goal of this phase is for the athlete to build a strength base with some hypertrophy thus aiding in the following phase when developing strength and power is the main emphasis. Developing this base will prepare the athlete for the higher intensity work of the strength/power phase. This is where volume per week decreases (351 reps/week) while intensity increases (80-95% 1RM).

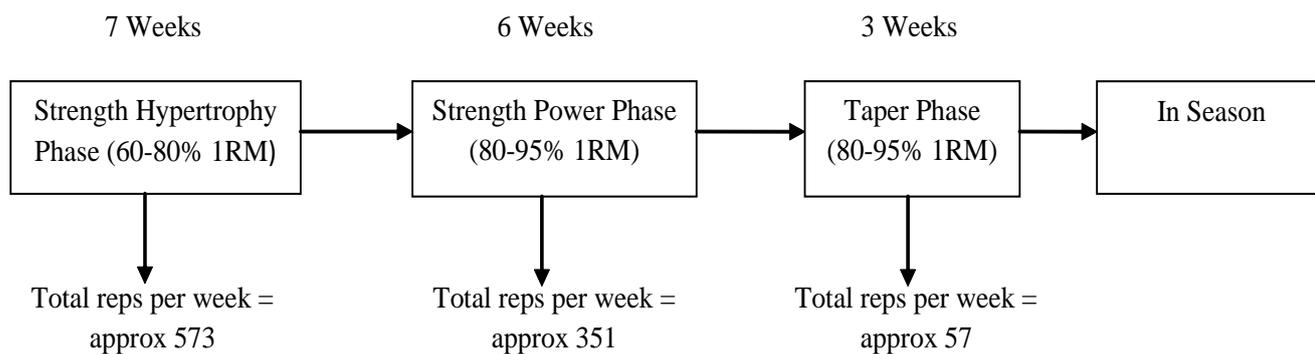


Figure 2. A proposed timeline leading into the season for implementing a taper

Twenty-one days before the season starts, the taper phase is implemented where intensity remains identical to the strength power phase (80-95% 1RM) but volume is drastically reduced (57 reps/week). Strength training is still performed during the taper phase as to retain strength, hypertrophy and power gains made from the previous two phases. Volume is kept low in order to reduce fatigue during the taper. A similar template can be used for any team sport and manipulated based on the specific needs of the sport.

Table 5. Example Strength/Hypertrophy Program During Preseason

Day 1 - Upper Body	Set/Rep	INT	Day 3 - Upper Body	Set/Rep	INT
A1. Bench Press	4x6	80%	A1. BB Row	4x6	80%
A2. Pushup	4x12-15		A2. YTLW	4x8	
B1. DB Incline Press	4x8	75%	B1. Chinup	4x8	
C1. DB Overhead Press	3x12	65%	C1. Inverted Row	3x15	
D1. Tricep Extension	3x12	65%	D1. DB Curl	3x10	
Day 2 - Lower Body	Set/Rep	INT	Day 4 - Lower Body	Set/Rep	INT
A1. Trap Bar Deadlift	5x5	83%	A1. Back Squat	5x5	83%
B1. Romanian Deadlift	4x8	75%	B1. Walking Lunge	4x8/leg	75%
C1. Glute Bridge	4x12	65%	C1. Backwards Sled Drag	6x2	
D1. Ab Wheel	3x10		D1. Hanging Leg Raise	3x10	
			D2. Side Plank	3x60sec/side	

Table 6. Example Strength/Power Program During Pre Season

Day 1 - Upper Body	Set/Rep	INT	Day 3 - Upper Body	Set/Rep	INT
A1. Push Press	5x3	87%	A1. Weighted Chin A2. Med Ball Overhead Throw	4x6 4x4	80%
B1. Bench Press B2. Explosive Med Ball Chest Pass	4x4 4x5	85%	B1. Banded Bench Pull	5x5	83%
C1. DB Incline Press	3x6	80%	C1. Farmers Walk	6x1	95%
D1. Cable Woodchop	3x10/side				
Day 2 - Lower Body	Set/Rep	INT	Day 4 - Lower Body	Set/Rep	INT
A1. Power Clean	5x3	87%	A1. Power Snatch	5x3	87%
B1. Deadlift B2. Broad Jump	4x4 4x1-3	85%	B1. Back Squat B2. Box Jump	4x4 4x1-3	85%
C1. Glute Ham Raise	3x6		C1. Bulgarian Split Squat	3x8/side	
D1. Hip Thrust D2. Ab Wheel	3x6 3x10	80%	D1. Heavy Sled Drag (20m)	5x1	

Table 7. Example Tapering Period Program

Day 1 - Full Body	Set/Rep	INT
A1. Power Clean	3x2	90%
B1. Front Squat	3x5	83%
C1. Bench Pull	3x6	83%
D1. Incline Press	3x6	83%

CONCLUSION

Improvements in performance and physiological stress have been shown after as little as seven days of reduced training. In addition, a long period of detraining has shown favourable results to increasing power output especially at higher velocities. The literature suggests that some training has to occur during the tapering period in order not to lose strength gains that may occur during a full training cessation. However, the effect on force/velocity profiles when undertaking low volume training through a tapering period may elicit results different to that of Anderson et al. (2) as the authors used a full training cessation. Still unexplained is how a significant increase in power at high velocities affects sporting performance and movements such as sprinting. Anderson et al. (2) only found this increase in an isolated movement. Furthermore, we do not know the optimal tapering duration for athletes involved in collision team sports and whether or not performance gains made from pre to post taper are sustained in the future weeks as training resumes as normal.

CHAPTER 3: STRENGTH, SPEED, AND POWER CHARACTERISTICS OF ELITE RUGBY LEAGUE PLAYERS

ABSTRACT

The purpose of this article was to compare strength, speed and power characteristics between playing position (forwards and backs) in elite rugby league players. A total of 39 first team players (height 183.80 ± 5.95 cm; body mass = 100.3 ± 10.7 kg; age 24 ± 3 years) from a National Rugby League club participated in this study. Testing included 10, 40m sprint times, sprint mechanics on an instrumented non-motorized treadmill, and concentric isokinetic hip and knee extension and flexion. Backs were observed to have significantly ($p < 0.05$) lighter body mass (ES=0.98), were significantly faster (10 m ES=1.26; 40 m ES=1.61) and produced significantly greater relative horizontal force and power (ES=0.87 and 1.04) compared to forwards. However, no significant differences were found between forwards and backs during relative isokinetic knee extension, knee flexion, relative isokinetic hip extension, flexion, prowler sprints, sprint velocity, contact time or flight time. The findings demonstrate that backs have similar relative strength in comparison with forwards, but run faster over-ground and produce significantly greater relative horizontal force and power when sprinting on a non-motorized instrumented treadmill. Developing force and power in the horizontal direction may be beneficial for improving sprint performance in professional rugby league players.

INTRODUCTION

Rugby league is an intermittent collision sport that involves frequent bouts of high-intensity activity (e.g. sprinting, tackling and wrestling) with short bouts of low-intensity activity (e.g. walking and jogging) (22). These high-intensity activities are highly dependent on fitness characteristics including strength, speed and power (20-22, 36). Assessing strength, speed and power allows strength and conditioning practitioners to create a profile of each individual athlete using these characteristics and track progress over time.

In rugby league, forwards and backs need similar functional skills such as tackling, passing and catching. However, these playing positions differ in physical and physiological characteristics (29, 34). Forwards generally carry a greater body mass and have greater strength most likely due to their position in the middle of the field, thus having to spend more time tackling the opposition (10, 29, 36). Conversely, backs can generally jump higher and sprint faster most likely due to their position on the edge of the field where these attributes serve an important purpose on offense and defence (10, 36). To date, there is minimal research comparing strength, speed and power characteristics between forwards and backs in elite rugby league. The existing literature has only published findings from simple field tests such as sprint times and vertical jump. Furthermore, there is very little research to date utilizing isokinetic dynamometry at the knee and hip joints, and instrumented treadmills for assessing sprint kinetics in elite rugby league (10, 36). Such information is vital for gaining a more accurate understanding of the positional differences between forwards and backs. This could potentially inform coaches of suitable positions for developing rugby league players and influence strength and conditioning coaches in how they program for positional and individual differences in rugby league. Therefore the purpose of this study was to compare strength, speed and power characteristics between playing position (forwards and backs) in elite rugby league players.

METHODS

Experimental Approach to the Problem

This cross sectional analysis investigated player position differences (i.e. forwards vs. backs) for isokinetic hip and knee strength, sprint kinetics and kinematics on a non-motorized

treadmill, and sprint times during over-ground sprinting with and without external resistance. Testing was completed during the National Rugby League (NRL) off-season.

Subjects

Thirty nine professional NRL players (mean \pm SD: height = 183.8 ± 5.95 cm; body mass = 100.3 ± 10.74 kg; age = 24 ± 3 years) volunteered as participants for this research. Of the 39 subjects, 22 were forwards and 17 were backs. All participants were free from any injury that would prevent maximal efforts during testing. The procedures for this study were approved by the Auckland University of Technology Ethics Committee. Subjects were informed of risks and benefits of participation in the study and signed informed consent.

Methodology

Prior to the testing, all subjects completed a standardized warm-up and familiarization protocol which consisted of three movements at an individually perceived 50, 70 and 90% of maximum exertion (8). Following the warm-up, participants were fastened to a Humac Norm dynamometer (Lumex, Ronkonkoma, NY, USA) to assess isokinetic concentric knee and hip extensor and flexor strength on the dominant leg at 100 Hz. The leg that the player preferred to kick the ball was defined as the dominant leg (7). The dynamometer was set up in two separate positions using a standardized protocol for knee and hip actions (37). The dominant leg was tested at a fixed angular velocity of $60^\circ \cdot s^{-1}$ for five extension and five flexion actions (32). A custom made LabVIEW program (Version 11.0, National Instruments Corp., Austin, TX, USA) was used to fit the torque-angle curves with a 4th order polynomial to identify peak torque using the average of the last four repetitions for the final value (8). Peak flexion torque was divided by the peak extension torque in order to determine hamstring to quadriceps ratios (H/Q ratio).

A non-motorized treadmill (NMT) (Woodway, Force 3.0, Waukesha, WI, USA) was used to measure maximum velocity sprint kinetics and kinematics. Following a warm-up, the subjects performed maximum effort sprints on the NMT. The NMT was instrumented with 4 embedded vertical load cells mounted under the running surface, and a mounted horizontal load cell connected to a non-elastic tether and waist harness. Subjects were instructed to

sprint maximally from a standing start and to reach and maintain maximum velocity for greater than 5 seconds. The data was collected at a sampling rate of 200 Hz allowing collection of vertical forces (F_v), horizontal forces (F_h) and power (P). The recorded data were filtered with a 4th order, low pass Butterworth filter with a cut off frequency of 50 Hz. Power was calculated as horizontal force multiplied by sprint velocity. Peak values of force and power over 10 steps at constant maximum velocity were averaged for a final value. Contact times (C_t) and flight times (F_t) were also averaged over the 10 steps. C_t was determined from the time of force applied to the treadmill was greater than 0 N, where as F_t was determined from the time between the ground contact periods. Stride frequency was determined from: $1/(C_t + F_t)$, where as stride length was determined from: running velocity/step frequency. The subjects completed two trials in order to determine within-session reliability for all variables on the NMT. The reliability of this testing in our laboratory was moderate-to-high with intraclass correlation coefficients (ICC) ranging between 0.79 – 0.97 and coefficients of variation (CV) ranging between 1.4 – 4.7%.

Sprint times were assessed using timing lights (Fusion SmartSpeed Timing Gates System, QLD, Australia). After a thorough warm up of dynamic flexibility and running at progressively faster speeds, participants completed two 40m sprints through the timing lights with at least 2 minutes of passive recovery. Participants were instructed to start the sprint from a standing split stance (left leg forward) and to maintain their effort past the last timing light. Sprint times were collected at 10m and 40m.

Statistical Analysis

All data are reported as means and standard deviations (SD) and statistical significance was set at $p < 0.05$. Independent t -tests were used to determine differences between the forwards and backs for all data. Significant differences were further analysed using effect size (ES). ES of < 0.2 , < 0.6 , < 1.2 and > 1.2 were considered trivial, small, moderate and large, respectively (25).

RESULTS

Significant differences were found between forwards and backs in the following tests and variables: body mass, 10 and 40 m sprint times, relative horizontal force and relative power (see Table 1). Forwards were significantly heavier than backs (+9%; ES=0.98). Backs were significantly faster over 10 m (+3.6%; ES=1.26) and 40 m (+5.3%; ES=1.61) compared to forwards. Furthermore, when horizontal force and power were made relative to body mass,

backs displayed significantly greater values than forwards (+23.3%; ES=0.87: +25.4%; ES=1.04 respectively).

Table 8. Strength, Speed & Power Characteristics of Elite Rugby League Players

	Forwards	Backs	Effect Size
Age	24 ± 3	24 ± 3	0
Anthropometry			
Height (cm)	185.0 ± 5.8	181.0 ± 5.7	0.61
Weight (kg)	104.0 ± 10.1	95.0 ± 9.3**	0.98
Sprint Performance Over Ground (s)			
10 m	1.72 ± 0.07	1.66 ± 0.03**	1.26
40 m	5.40 ± 0.27	5.11 ± 0.09**	1.61
Sprint Kinetics & Kinematics			
Woodway			
Peak Vertical Force (N)	2589 ± 364	2449 ± 239	0.47
Mean Vertical Force (N)	1550 ± 210	1438 ± 110	0.70
Relative Vertical GRF (N)/kg	14.62 ± 0.88	15.01 ± 1.08	0.36
Horizontal Force (N)	314 ± 52.08	343 ± 79.94	0.45
Relative Horizontal Force (N)/kg	2.94 ± 0.49	3.63 ± 0.88*	0.87
Power (W)	1957 ± 341	2220 ± 535	0.60
Relative Power (W/kg)	18.54 ± 2.94	23.24 ± 5.98*	1.04
Contact Time (ms)	167 ± 10.60	160 ± 10.49	0.67
Flight Time (ms)	75.8 ± 10.12	74.14 ± 11.58	0.15

Isokinetic (N.m)**Relative Peak Torque**

Knee: Extension	2.11 ± 0.83	1.88 ± 1.05	0.10
Knee: Flexion	1.19 ± 0.44	1.14 ± 0.63	0.09
Hip: Extension	3.08 ± 1.14	2.93 ± 1.60	0.15
Hip: Flexion	1.30 ± 0.47	1.20 ± 0.64	0.35

Relative Extension/Flexion Ratio

Knee	0.58 ± 0.13	0.62 ± 0.14	0.27
Hip	0.43 ± 0.06	0.42 ± 0.08	0.10

*Significant difference ($p < 0.05$) between forwards and backs

DISCUSSION

The results of this investigation confirmed that there are moderate to large differences in selected physical qualities between positions in elite rugby league players. Backs were observed to have significantly lighter body mass (ES=0.98), were significantly faster (10 m ES=1.26; 40 m ES=1.61) and produced significantly greater relative horizontal force and power (ES=0.87 and 1.04) compared to forwards. Forwards were found to be generally taller and significantly heavier than their back counterparts. However, no significant differences were found between forwards and backs during relative isokinetic knee extension, knee flexion, relative isokinetic hip extension, flexion, sprint velocity, contact time or flight time. These physical differences are likely due to selection bias and the demands of the separate positions. Forwards are involved in significantly more tackles than backs and travel less distance per game (29, 34). The greater body mass of forwards allows them to win the collision, and thus potentially restart play before the opposition defensive line is ready. On the other hand, the lighter backs average significantly greater sprinting distances and durations at high velocity during a rugby league match (34).

Significant differences in sprinting performance over 10 m and 40 m were found between forwards and backs (Table 8). Backs were significantly faster than forwards which

aligns with the findings of Meir et al. (36) on professional rugby league players but contrasts with Comfort et al. (10) where the authors found no significant differences between forwards and backs during the sprint. This may have been due to the different equipment used in measuring time over the sprint. The present study and Meir et al.(36) used timing lights while Comfort et al. (10) used a speed gun.

While no significant differences were observed in vertical force or sprint kinematics, backs showed significantly faster 10 m and 40 m sprint times over ground. Significant differences in relative horizontal force (ES=0.87) and relative power (ES=1.04) were also found and these factors may be contributing factors to the faster sprint times recorded by the backs. Morin et al. (38) reported that maximal power was found to be strongly correlated with maximal speed and 4s distance ($r=0.863$ and 0.892 respectively). Furthermore, the authors found a significant correlation between the index of force application and maximal speed and 4s distance ($r=0.875$ and 0.683 respectively). Thus it could be suggested that the magnitude of force and power produced in the intended direction of movement has an influence on performance. Additionally, the current study found that athletes that can display high levels of horizontal force and power relative to body mass had superior sprint times.

There were no significant differences in relative isokinetic values between forwards and backs. Comfort et al. (10) also observed similar findings in isokinetic strength in elite English rugby league players. However, sprint times and sprint kinetics were different. Thus, despite similar strength levels, faster athletes were able to produce more force in the ground in the horizontal direction. This finding suggests that with relative force being equal between athletes, further improving horizontal force production may potentially improve sprint performance.

PRACTICAL APPLICATIONS

These findings suggest that developing rugby league players with greater horizontal force and greater sprinting abilities may be best suited to positions in the backs. Backs were faster than forwards over 10 m and 40 m and furthermore, backs produced greater relative horizontal force and power while no other variables were found to be significantly different. These data suggests that the magnitude of force produced may not be as important as the direction the force is applied in during short distance sprinting. Thus, for backs to improve sprinting performance and therefore potentially on field performance, developing force and power capabilities in the horizontal direction may be beneficial in

addition to improving overall force and power capabilities. Certain loaded and unloaded movements can be used in order to develop horizontal force and power. For example, some exercises to develop horizontal force are hip thrusts, back extensions, reverse hypers, heavy sled drags, heavy sled pushes. Horizontal power can be developed using kettlebell swings and various weighted ball throws. Plyometric exercises such as broad jumps and bounding also assist in developing force and power in the horizontal direction.

CHAPTER 4: THE EFFECTS OF TAPERING ON POWER-FORCE-VELOCITY PROFILING AND JUMP PERFORMANCE IN PROFESSIONAL RUGBY LEAGUE PLAYERS

ABSTRACT

The purpose of this study was to investigate the effects of a pre-season taper on individual power-force-velocity profiles and jump performance in professional National Rugby League (NRL) players. Seven professional rugby league players performed concentric squat jumps using ascending loads of 25, 50, 75, 100% body mass before and after a 21 day step taper leading into the in-season. Linear force-velocity relationships were derived and the following variables were obtained: maximum theoretical velocity (V_0), maximum theoretical force (F_0) and maximum power (P_{max}). The players showed likely-to-very likely increases in F_0 ($ES=0.45$) and P_{max} ($ES=0.85$) from pre to post taper. Loaded squat jump height also showed likely-to-most likely increases at each load ($ES=0.83-1.04$). The 21 day taper was effective at enhancing maximal power output and jump height performance in professional rugby players, possibly due to a recovery from fatigue and thus increased strength capability after a prolonged preseason training period. Rugby league strength and conditioning coaches should consider reducing training volume while maintaining intensity and aerobic conditioning (e.g. step taper) leading into the in-season.

INTRODUCTION

Rugby league is a collision sport that involves high intensity bouts of exercise exertion (34). Players are required to complete frequent bouts of high intensity activity (e.g. sprinting and tackling) separated with short bouts of low intensity activity (e.g. walking and jogging) (29, 34). Due to these activities, players require high muscular strength and power in addition to well developed aerobic capacity (34, 36). Professional rugby league players typically have a scheduled match every 5-10 days during the in-season, thus recovery is an important aspect in reducing an athlete's fatigue that can be accumulated prior to and throughout the in-season. The season structure typically involves a 4 month pre-season, 6 month in-season and one month for the playoffs if the team is successful.

A key element to an athlete's preparation for competition is the taper. A taper is a reduction in training load over a period of time that allows an athlete to recover from the stress of training. In doing so, performance benefits can be enhanced following a tapering period such as: maximal power, vertical jump, 10-40 m sprint times and isoinertial strength (12, 14, 23). While these traditional strength and speed measures allow some diagnostic information, they do not incorporate the entire force-velocity spectrum. The force-velocity mechanical capabilities of the neuromuscular system are well described by the inverse force-velocity and parabolic power-velocity relationships when multi joint movement are considered (44). Maximum theoretical force (F_0) and velocity (V_0) are extreme values identified as the x- and y-intercepts of the force-velocity relationship, and the ratio between F_0 and V_0 determines the individual F-v profile (S_{fv}). The F-v profile and maximal power (P_{max}) have been shown to have independent influences on performance during squat jumping (47). No previous research has investigated the effect of tapering on force-velocity profiling in addition to performance measures in team sports. Such information is vital for determining the efficacy of tapering in team sports. Therefore the purpose of this study was to determine the effects of tapering on power-force-velocity profiling and jump performance.

METHODS

Experimental Approach to the Problem

This study investigated the effects of tapering on force-velocity profiling and loaded squat jump performance in a group of seven professional rugby league players. All subjects performed loaded squat jumps with 25, 50, 75 and 100% of their body mass before and after

a step taper. The step taper occurred during the final 21 days of a four month pre-season training period leading into the Australian National Rugby League (NRL) in-season. Jump height was measured for each load and linear force-velocity profiles were derived. The measures of F0, V0, Pmax and jump height at each load were compared pre- and post-taper.

Subjects

Seven professional male rugby league players (age: 24 ± 3.6 ; height: 183.0 ± 6.1 cm; weight: 99.0 ± 12.2 kg), including 2 international players, from an NRL club volunteered as participants for this research. Each participant signed an informed consent prior to participation. The Auckland University of Technology Ethics Committee (AUTEK) approved all procedures undertaken in this study (12/159).

Methodology

Athletes attended one testing session at the start of the taper and one testing session at the end of the taper. During the first testing session, each athlete lay on their back for extended leg length measurement. This measurement was made on the right leg from the greater trochanter to the end of the participant's toes which were pointed towards the floor (i.e. plantar flexed) to simulate the take off position during a squat jump. The participant then stood up and squatted down to a 90° knee angle which was measured by a goniometer. From this position, a measurement was taken from the greater trochanter to the floor (H_s) and the crease between the gluteals and hamstrings to the floor (45). The second measurement was made to provide the height of the box the athlete would touch before jumping as fast as possible vertically. Following a general 5 minute warm-up, the testing protocol consisted of two, concentric only squat jumps at five different additional loads at a percentage of body mass (25, 50, 75 & 100% BM). Jump height was measured with a linear position transducer (Gymaware, Australia) attached to the barbell sleeve and placed outside the rack so the wire would be vertical once the athlete stepped back to the box with the barbell across his shoulder. To control the depth of the concentric only loaded squat jump, a box was placed in the squat rack for the participant to touch before jumping as fast as possible vertically. The height of the box was determined by the measurement taken from the crease between the gluteals and hamstrings to the floor while in the 90° knee angle squat position. Once the participants warmed up, they each had two bodyweight concentric only squat jumps to familiarise themselves with the testing protocol. During each jump throughout the testing, the

investigator signalled when to jump after the pause on the box through verbal cueing. This minimised the likelihood of participant jumping too early and utilising the stretch-shorten cycle.

Data Analysis

The vertical push-off distance (H_{PO}) during the squat jump was determined by the difference between H_s and the extended leg length. With only measures of H_{PO} , jump height (h) and moving mass (body mass + additional mass), mean force and velocity over the push-off were calculated at each load with the following equations (45)

$$\text{Mean force} = mg((h/H_{PO})+1)$$

$$\text{Mean velocity} = \sqrt{(gh/2)}$$

Then, linear force-velocity relationships were calculated through least squares regressions, and S_{FV} was determined as the slope of the force-velocity relationship (44). The force-velocity curves were extrapolated to identify F_0 and V_0 as the x- and y-intercepts on the force-velocity curve (46). Finally, P_{max} was calculated as:

$$P_{max} = F_0 \times V_0/4$$

Taper

A step taper was utilised during the final 21 days of a four month preseason training period, where the volume of strength training rapidly decreased while intensity remained high and conditioning remained unchanged (43). Strength training was performed three to four times a week averaging ~60 mins a session before the taper. Field sessions were performed three to four times a week averaging ~60 mins a session. During the taper, strength training was reduced to one session per week taking ~45 mins while field sessions remained at pre taper levels. Intensity relative volume (IRV) per session was used to quantify resistance training load and volume during these training phases (35). The first seven weeks of the preseason was the strength/hypertrophy phase where an IRV of 358.4 per week was calculated. During this phase, the athletes typically performed high repetitions (6-15 reps) with moderate loads (65-83% 1RM). The following six weeks were a strength/power phase where an IRV of 156.9 per week. During this phase, athletes typically performed moderate

repetitions (3-6 reps) with moderate to heavy loads (80-95% 1RM). The three week taper leading into the season had an IRV of 40.8 per week which is shown in table 1.

Table 9. Resistance training program used during the taper period

Taper Program	Set/Rep	INT
A1. Power Clean	3x2	90%
B1. Overhead Squat	3x6	80%
C1. Bench Press	3x5	82%
D1. Bench Pull	3x5	82%

INT=% of 1RM, Rep=repetitions

Statistical Analysis

For practical significance and due to the small sample of elite rugby league players, magnitude-based inferences were determined with a modified statistical Excel spreadsheet (24). Effect size and 90% confidence limits (ES \pm CL) were calculated to compare the difference between pre and post means. 0.2 was pre-specified as the smallest worthwhile difference (SWD) for between-subjects standard deviations (SD). Threshold values of 0.2, 0.6, 1.2, 2.0 and 4.0 were used to represent small, moderate, large, very large and extremely large effects. Probabilities that differences were higher, lower or similar to the SWD were evaluated qualitatively as: $\leq 1\%$, almost certainly not; $>1-5\%$, very unlikely; $>5-25\%$, unlikely; $>25-75\%$, possible; $>75-95\%$, likely; $>95-99\%$, very likely; $>99\%$, most likely. If the chance of both higher and lower values was $>5\%$, the true difference was assessed as unclear.

RESULTS

Table 10. Mechanical and performance variables of professional rugby league players pre- and post-taper

	Pre Taper	Post Taper	ES ± CL	Inference
F0 (N/kg)	54.93 ± 25.71	64.74 ± 16.87	0.45 (0.05;0.85)	Small*
V0 (m/s)	2.71 ± 0.63	2.86 ± 0.58	0.24 (-0.44;0.91)	Small
Pmax (W/kg)	34.87 ± 10.97	44.71 ± 6.72	0.85 (0.46;1.24)	Moderate**
Sfv	-22.39 ± 14.09	-24.09 ± 9.69	0.23 (-0.26;0.72)	Small
Jump 25% (cm)	39.59 ± 8.52	47.74 ± 4.65	0.90 (0.20;1.60)	Moderate*
Jump 50% (cm)	31.66 ± 8.49	42.09 ± 4.63	1.04 (0.65;1.42)	Moderate***
Jump 75% (cm)	25.41 ± 9.13	36.39 ± 6.49	0.94 (0.58;1.30)	Moderate***
Jump 100% (cm)	21.20 ± 9.51	30.30 ± 5.08	0.83 (0.38;1.28)	Moderate**

Unclear, *Likely positive, **Very Likely positive, ***Most Likely positive, F0= theoretical maximum force, V0=theoretical maximum velocity

F0, V0, Pmax and jump performance at each load pre to post taper are presented in Table 2. F0 had a likely small increase from pre- to post-taper while any improvements in V0 and S_{fv} were unclear. Pmax and four jump heights at 25, 50, 75, 100% BM showed likely-to-most likely moderate increases from pre to post taper.

DISCUSSION

An interesting observation from the present findings was that V0 was not enhanced while F0 was likely to increase following the taper. S_{fv} became slightly more negative from pre to post taper which shows the slope of the force-velocity profile moving in the direction towards force capabilities, although the change was unclear. It could be speculated that velocity capabilities would change more so than force capabilities as shown in Anderson et al. (2). The greater change in F0 rather than V0 may have occurred due to the short tapering period that was utilized in the present study. The taper in the present study lasted 21 days while Anderson et al., (2) used a three month detraining period. If the taper in the present study was longer a greater change in V0 may have taken place due to the overshoot phenomenon (1, 2). However, Coutts et al. (12) observed similar findings to the present study with their short 7 day taper where no significant changes were observed with higher velocity isokinetic strength (5.25 rad.s⁻¹). Thus velocity capabilities may have improved if the taper had occurred over a longer duration. Furthermore, the training done before the taper was predominantly heavy loaded strength training with a few low and unloaded explosive

movements. If velocity was the prominent quality being developed pre taper, we may have observed a greater change in V_0 .

The initial benefit of increased force production may have been due to recovery of fatigue from prolonged training. This has been shown by Coutts et al. (12) where isoinertial strength and isokinetic strength at slower velocities ($1.05\text{rad}\cdot\text{s}^{-1}$) both significantly increased from pre to post seven day taper. Furthermore, Elloumi et al. (14) reported a total score of fatigue significantly lower during and after their 2 week taper in sixteen national level 7s rugby players compared to six weeks of intense training. Previous tapering literature in rugby and rugby league have used 7 and 14 day tapers showing significant increases in performance measures (i.e 10 m sprint and 5 jump test) (12, 14). This may have been due to a potential increase in maximal power gained from the tapering period. Coutts et al. (12) attributed the increase in strength, power and endurance to a change in muscle fibre properties, increased anabolism and a decrease in muscle damage. Elloumi et al. (14) attributed their performance increases to a reduction in fatigue. The present study also saw improvements in performance that can potentially attribute this to the very likely increase in P_{max} . Both the present study and Coutts et al. (12) utilised a step taper while Elloumi et al. (14) utilised a progressive taper. Training time decreased by 55% during the 7 day step taper in Coutts et al. (12), while Elloumi et al. (14) had weekly duration of training sessions decrease by 33% over the 2 week taper. The present study decreased weekly reps by ~80%. The current literature suggests either a step or progressive taper for increasing or maintaining maximal power (6). Both the present study and Coutts et al. (12) have shown a step taper is effective at improving performance variables.

A limitation of the present and previous studies was there was no control group used (12, 14). In addition to this, testing was only performed once pre taper and once post taper so long term effects of the taper were not investigated. Further research should investigate how long these improvements in P_{max} last following the taper and how they affect athletic performance (e.g. 1RM strength, repeat sprint ability, sprinting and jumping).

PRACTICAL APPLICATIONS

These findings suggest that a 21 day taper is long enough to elicit a positive change in maximal power and performance. Furthermore, it seems that strength training is the driving factor in the change of force, velocity and power variables where running based conditioning does not have an adverse effect. This is important to note for strength and conditioning

coaches as fitness and conditioning does not have to be sacrificed in order to see positive changes in maximal power during a taper. Most importantly during the taper, volume should be reduced while intensity is kept high.

It is still not known the optimal length for a taper in rugby league that produces the greatest change in maximal power. When implementing a step taper where strength training volume is greatly decreased, we suggest starting earlier than the traditional one week training load reduction leading into the in-season. This step taper would start three weeks before the in-season and therefore, coaches should consider starting in-season strength training during the last phase of pre season strength training (i.e. 1-2 strength sessions a week while the training intensity and aerobic conditioning levels remain high). This would allow adaptations in maximal power to take place and the athlete's to recover from prolonged training while still improving conditioning specific to the sport. Thus coaches can implement a step taper to potentially improve Pmax and performance leading into a season while avoiding fatigue and still improving or maintaining aerobic and anaerobic conditioning.

CHAPTER 5: GENERAL DISCUSSION AND PRACTICAL APPLICATIONS

PREFACE

This chapter is a synthesis of the findings of this thesis with practical application, in context with the current literature. The goal is to enhance the current understanding of strength, speed and power characteristics in rugby league, tapering in team sports and the effect of tapering on the power-force-velocity profile and performance. This chapter ends with a conclusion of the thesis as a whole.

GENERAL DISCUSSION

On the basis of the literature review focusing on tapering of resistance training in team sports, it was established that improvements in physiological and performance variables would occur after a taper as short as 7-14 days. Significant improvements in T:C and CK have been shown to occur after 7 and 14 day tapers (12, 26). Based on the literature, it seems that the type of sport the subjects are involved in will determine if a significant change in T:C or CK will occur (12, 26). Sports that cause a high level of muscle trauma (i.e. rugby league, American football, powerlifting) allow for greater change due to the already elevated physiological measures going into the taper compared to endurance sports.

The research suggests performance in jumping and sprinting improves from pre to post taper. Previous literature suggests this could be due to changes in muscle fibre properties (1, 2). Anderson et al. (1, 2) found maximal unloaded movement speed and power increased significantly after a tapering period. This was due to an increase in the proportion of fast MHC and a shift towards faster MHC phenotypes (fast twitch type IIA to fast twitch type IIX) that occurred over the tapering period. Type IIX muscle fibres contract approximately twice as fast as type IIA fibres which may help to explain the performance improvements of the jumping and sprinting as these are very high velocity movements that involve fast twitch muscle fibres (5, 31).

Conflicting evidence has been observed in isoinertial and isokinetic strength in previous literature. On one hand, isoinertial and isokinetic strength has been shown to improve significantly from pre to post taper (12). In contrast, Garcia-Pallares et al. (23) observed significant decreases in isoinertial strength in the training cessation group. The conflicting findings may have come down to Coutts et al. (12) still implementing strength

training during the taper while Garcia-Pallares et al. (23) did not. This may have allowed the athletes to recover while maintaining strength acquired pre taper. Furthermore, Coutts et al. (12) utilized a 7 day step taper while Garcia-Pallares et al. (23) used 4 weeks of training cessation which may have facilitated a detraining effect.

To date, only one study has investigated the force/velocity relationship pre and post taper (2). Our findings differed from this previous research. We observed V_0 was not enhanced while F_0 was likely to increase following a 21 day taper. Also in the current study S_{fv} became slightly more negative which shows the slope of the force-velocity profile moving towards force capabilities, although the change was unclear. In contrast, Andersen et al. (2) found significant increases in peak velocity, peak rate of force development and angular acceleration post taper. The differing tapering protocols may be the reason for these conflicting results. Andersen et al. (2) implemented a three month detraining period while our research implemented a 21 day step taper. Coutts et al. (12) observed similar results to ours where isoinertial strength and isokinetic strength at slower velocities ($1.05 \text{ rad}\cdot\text{s}^{-1}$) both significantly increased from pre to post seven day step taper. If we utilized a longer tapering period, velocity capabilities may have improved as per Andersen et al. (2). Furthermore, the training performed pre taper was predominantly heavy loaded strength training with a few low and unloaded explosive movements. If velocity was the prominent quality being developed pre taper, we may have observed a greater change in V_0 .

Performance measures (i.e 10 m sprint and 5 jump test) have been shown to improve with 7 and 14 day tapers in rugby and rugby league (12, 14). This may have been due to a potential increase in maximal power gained from the tapering period which has been shown to occur in this thesis. The current literature suggests either a step or progressive taper for increasing or maintaining maximal power (6). Both this thesis and Coutts et al. (12) have shown a step taper is effective at improving performance variables.

Recommendations

- Develop horizontal force and power to improve short sprint speed using loaded and unloaded movements. For example, some exercises to develop horizontal force are hip thrusts, back extensions, reverse hyperextension, heavy sled drags, heavy sled pushes. Horizontal power can be developed using kettlebell swings and various weighted ball throws. Plyometric exercises such as broad jumps and bounding also assist in developing force and power in the horizontal direction.

- A tapering period between 7-14 days seems to be ideal to elicit positive changes in performance and physiological measures. A step reduction taper seems to be the most effective with short tapering periods (14 days or less). During the taper, resistance training intensity should be maintained or increased while volume should decrease compared to pre taper programming.
- The taper can be used in additional scenarios that may benefit the athlete and team as tapering periods can be as short as 7 days. These could be at the end of a preseason, before the playoffs, during bye weeks and identifying athletes that are in need of a taper by monitoring fatigue and performance.
- It is suggested starting earlier than the traditional one week training load reduction leading into the in-season. This step taper would start three weeks before the in-season and therefore, coaches should consider starting in-season strength training during the last phase of pre season strength training (i.e. 1-2 strength sessions a week while the training intensity and aerobic conditioning levels remain high).
- F-v profiling can be used to determine whether an athlete is more force or velocity based. Thus allowing strength and conditioning coaches to prescribe either force or velocity based training based on the athlete's individual profile to improve power output.

Future Considerations

It is still not known the optimal length for a taper in rugby league that produces the greatest change in maximal power and performance. Further research should investigate how long these improvements in Pmax last following the taper and how they affect athletic performance (e.g. 1RM strength, repeat sprint ability, sprinting and jumping).

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Appendix 1: Ethics Approval, Auckland University of Technology Ethics Committee



2 December 2013

Matt Brughelli
Faculty of Health and Environmental Sciences

Dear Matt

Re Ethics Application: **13/350 The effects of tapering on force/velocity profiles and performance measures in professional rugby league players.**

Thank you for providing evidence as requested, which satisfies the points raised by the AUT University Ethics Committee (AUTECS).

Your ethics application has been approved for three years until 2 December 2016.

As part of the ethics approval process, you are required to submit the following to AUTECS:

- A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/researchethics>. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 2 December 2016;
- A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/researchethics>. This report is to be submitted either when the approval expires on 2 December 2016 or on completion of the project.

It is a condition of approval that AUTECS is notified of any adverse events or if the research does not commence. AUTECS approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTECS grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

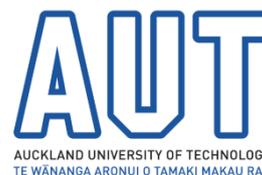
To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

A handwritten signature in black ink, appearing to read 'K O'Connor', written in a cursive style.

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: James de Lacey james.delacey01@gmail.com



Participant Information Sheet

Date Information Sheet Produced: 5th November 2013

Project Title

THE EFFECTS OF TAPERING ON FORCE/VELOCITY PROFILES AND PERFORMANCE IN PROFESSIONAL RUGBY LEAGUE PLAYERS

Introduction

My name is James de Lacey. I am a student completing my Masters Degree in Sport and Exercise Science at AUT University, Auckland. I am interested in determining the effects of tapering on force/velocity profiles and performance. The purposes of this research are to: 1) develop a set of normative data for rugby league players; 2) determine reliability of force, velocity and power variables; 3) determine relationships between force, velocity and power variables; and 4) determine the effects of a 10 day taper on force, velocity and power variables.

Invitation to participate

- You are invited to take part in the above mentioned research project during the week of April 13th – 23rd. Your participation in this research is voluntary. You are free to withdraw consent and discontinue participation at anytime without influencing any present and/or future involvement with the Auckland University of Technology.
- Your consent to participate in this research will be indicated by your signing and dating the consent form. Signing the consent form indicates that you have freely given your consent to participate, and that there has been no coercion or inducement to participate by the researchers from AUT. Participants will be taken on a first come, first serve basis. If you do not wish to participate, you will not perform the testing protocols and continue training as usual.

What is the purpose of the study?

- The purposes of this research are to: 1) develop a set of normative data for rugby league players; 2) determine inter and intra-class session reliability of force, velocity and power variables; 3) determine relationships force, velocity variables; and 4) determine the effects of a 10 day taper on force, velocity and power variables.
- This study is being conducted as part of a Masters Degree thesis. The results of this study will be submitted to peer-reviewed journals.
- The 10 day taper will involve a reduction in training load where only 1-2 strength sessions/week and 1-2 field sessions/week will be undertaken.

How was I chosen to be asked to participate in the study?

- Because you are part of the Warriors NRL Club

What happens in the study?

You will be asked to perform the following tests on 3 different occasions:

1. Concentric only squat jump at 5 different percentages (0, 25, 50, 75, 100%) of body weight.

You will perform 5 different jumps with different additional loads of body weight (0, 25, 50, 75, 100%) with a barbell on your back. Each jump you will try jump as high as you can, you will get 2 trials at each additional load. You will get 1-2mins rest between each jump.

2. Force/velocity jump profile. Vertical CMJ

You will perform 2 jumps with no added load. There will be no arm swing and you will have 10-30sec rest between each jump.

3. Sprint 30m.

You will perform 2 sprints for 30m from a dead start. You will start with a split stance and on the researchers command, sprint with maximal effort.

4. Maximal Isometric Midhigh Pull

You will perform 3 pulls holding an immovable bar placed at midhigh height for 5 seconds. You will grip the bar with a double overhand grip and on the researchers command, pull the bar up as hard and as fast as you can until you are told to stop. You will get 30-45sec rest between each attempt.

5. Functional jumping profile (broad jump)

You will perform 2 standing long jumps for distance. Starting on the force plate, you will jump as far as you can onto a soft mat with 10-20sec rest between each attempt

What are the discomforts and risks?

With any form of exercise there is some risk of muscle soreness and/or injury. This testing is intensive in nature and does have some inherent risk associated with it, including musculoskeletal injury or soreness.

What are the benefits?

By participating in this study, you are providing us with the opportunity to collect data which will benefit us in identifying force/velocity profiles and understand the effects of tapering on performance. In turn, this will benefit the strength and conditioning community and also help you as an athlete to better your performance through individual force/velocity profiles that could individualise training further in the future.

What compensation is available for injury or negligence?

- In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How is my privacy protected?

- The data from the project will be coded and held anonymously in secure storage under the responsibility of the principal investigator of the study in accordance with the requirements of the New Zealand Privacy Act (1993).
- All reference to participants will be by code number only in terms of the research thesis and publications. Identification information will be stored on a separate file and computer from that containing the actual data.
- Only the investigators will have access to computerised data.
- Should a situation occur where you become injured then your identified next-of-kin / legal guardian / parent that has been recorded and/or signed the consent form will be contacted to advise them of the injury, the care provided and where you have been transferred to. The information obtained will also be passed onto the healthcare service as part of the on-going management of your medical care.

What are the costs of Participating?

There are no costs to participate, apart from scheduling your time to be available for testing. The testing sessions will last approximately 1.5 hours on 3 separate occasions.

Opportunity to consider invitation

- Please take the necessary time you need, up to 1 full week, to consider the invitation to participate in this research.
- It is reiterated that your participation in this research is completely voluntary.
- If you require further information about the research topic please feel free to contact James de Lacey or Matt Brughelli (details are at the bottom of this information sheet).
- You may withdraw from the study at any time without there being any adverse consequences of any kind.
- You may ask for a copy of your results at any time.
- You can withdraw both your data and the participation at any time prior to the end of data collection.

How do I join the study?

If you would like to participate in this research, please fill in and sign the attached *Consent Form*. You will be given a copy of the consent forms with this information sheet. If you do not return a signed consent form you will not be allowed to participate in the study.

Participant concerns

If you have any questions please feel free to contact James de Lacey or Matt Brughelli. Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor – Matt Brughelli.

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Kate O'Connor, koconnor@aut.ac.nz or phone 921 9999 ext 6038.

Researcher Contact Details:

James de Lacey, School of Sport and Recreation, Auckland University of Technology. Email: james.delacey01@gmail.com or phone +64 21 148 1087

Project Supervisor Contact Details

Primary Supervisor: Dr Matt Brughelli, Sports Performance Research Institute New Zealand, School of Sport and Recreation, Auckland University of Technology. Email: mbrughelli@aut.ac.nz or phone +64 9 921 9999 ext .7025

Secondary Supervisor: Dr. Mike McGuigan, Faculty of Health and Environmental Sciences, School of Sport and Recreation, Auckland University of Technology. Email: mmcquiga@aut.ac.nz

Additional Supervisor: Dr. Keir Hansen, High Performance Sport New Zealand. Email: keir.hansen@hpsnz.org.nz

Thank you for considering participating in this research.

Approved by the Auckland University of Technology Ethics Committee on 2013.

AUTEK Reference number /

Consent to Participation in Research - Player

Title of Project: **The effects of tapering on force/velocity profiles and performance in professional rugby league players**

Project Supervisor: **Dr Matt Brughelli**

Researcher: **James de Lacey**

- I have read and understood the information provided about this research project designed to measure the effects of tapering on force/velocity profiles and performance
- I have had an opportunity to ask questions and to have them answered.
- I understand that taking part in the study is entirely my choice and that I may withdraw any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- If I withdraw, I understand that all relevant information will be destroyed.
- I permit the researcher to use the data from testing that is part of this project exclusively for research or educational purposes
- I understand that any information I give during this study will be confidential and my name will not be recorded on any collected data at any time.
- I agree to participate in the research.
- I wish to receive a copy of the report from the research: tick one: Yes No

Player's signature:

Player's Name:

Date:

Project Supervisor Contact Details:

Dr Matt Brughelli,

Sports Performance Research Institute New Zealand,

School of Sport and Recreation,
Auckland University of Technology.

Private Bag 92006

Auckland 1020

64 9 921 9999 ext .7025

mbrughelli@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 2013

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