THE EFFECT OF TWO-EQUAL VOLUME TRAINING PROTOCOLS UPON STRENGTH, BODY COMPOSITION AND SALIVARY HORMONES IN STRENGTH TRAINED MALES

Taati Heke

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TABLE OF CONTENTS

ATTESTATION OF AUTHORSHIP

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

Taati Owen Lance Heke

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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ABSTRACT

Resistance training has been used extensively for improving muscle strength and athletic performance. Researchers have reported that training volume was one of the most important variables for improving strength and performance. This has been highlighted by greater performance improvements when performing three sets per exercise compared to a single set. Two commonly used training protocols are the full body (FB) and split body (SB) protocols, both of which have been used by athletes to improve training adaptations. However, very little research has directly compared the effects of FB and SB protocols. Muscle tissue growth is one important aspect of the adaptive process with testosterone (T), the main anabolic hormone, and cortisol (C), the primary catabolic hormone, being key contributors. Although many training studies have compared the effects of different protocols upon performance and hormones, none have been equated for training volume. Therefore, this study sought to examine the effects of two equivolume training protocols (FB and SB) upon strength, body composition and hormones (resting T and C) in strength-trained males.

Using a crossover study design, twenty four strength-trained males (mean 29.8 ± 6.8 years; mean 92.9 ± 12.2 kg) with a minimum of two years resistance training experience were randomly allocated into either a FB or SB training protocol. All subjects performed each protocol for four weeks separated by an eight-week wash-out period. Each training protocol involved three weekly workouts with the same number of sets and repetitions performed across each week. Rest periods were 60 seconds between sets and 90 seconds between exercises. Saliva samples were collected to assess the T and C responses to training. Body composition was assessed by skinfold assessments and maximal strength was determined by one repetition maximum (1RM) assessments.

Dependent t-tests were used to analyse within-group changes in the outcome variables, while independent t-tests were used to analyse the between-group differences in these variables. Statistical significance was set at an alpha level of $p < 0.05$.

There were a number of significant within-group changes, in particular, both protocols showed significant increases in strength ($p < 0.01$) and decreases in fat mass ($p < 0.05$) and percent body fat ($p < 0.05$). The resting hormonal responses were less consistent with SB producing significant increases in Sal-T ($p < 0.05$), while there were no significant changes in Sal-C ($p > 0.05$) after both training protocol. There was also a significant difference ($p < 0.05$) between training protocols observed for the Sal-T/C ratio.

Both the FB and SB training protocols appeared to be effective during a four week training period with similar strength and body composition changes observed. There were differences in our hormonal data but these results may have been due to differences in baseline levels. Future research should address the possible effects of longer training periods using the same training protocols examined in this study. This analysis would provide a better understanding of the underlying stimulus for subsequent training adaptations. It also appears that using a high weekly training volume and training frequency (three or more training sessions per week) may provide a greater stimulus for muscle hypertrophy and strength improvements compared to performing one or two training sessions per week.

1.0 CHAPTER ONE – INTRODUCTION

Coaches, trainers and instructors are continuously looking for ways to enhance the force-generating qualities of muscle to improve functional performance during every day and sport-specific tasks. Resistance training is well established as an effective exercise method for developing muscular fitness (i.e. the ability to generate muscle force) and is recommended for inducing muscle size and/or performance (e.g. strength, power, strength endurance) changes in both athletic and non-athletic populations (W.J. Kraemer et al., 2002).

Factors to consider when designing a resistance training programme include training load, repetition/s, sets and frequency, which in turn influence training volume. Training volume is defined as the load times the number of repetitions and sets (i.e. load x repetitions x sets), or more classically by the number of repetitions and sets (Fleck, 1999; Pearson, Faigenbaum, Conley, & Kraemer, 2000). The importance of training volume is supported by greater gains in muscle size and/or strength when performing three sets (per exercise) compared to one set (Marx et al., 1998; M. R. Rhea, Ball, Phillips, & Burkett, 2002). Moreover, modifying training volume was found to maximise increases in lean body mass and functional performance (Potteiger, Judge, Cerny, & Potteiger, 1995). However, there does appear to be an "optimal" training volume and once this threshold is reached no further gains will result (Gonzalez-Badillo, Gorostiaga, Arellano, & Izquierdo, 2005).

Many training studies have compared the effects of different resistance training protocols upon body size, body composition and/or muscle performance (Abe, Kojima, Kearns, Yohena, & Fukuda, 2003; Ahtiainen, Pakarinen, Alen, Kraemer, & Hakkinen, 2005; Bird, Tarpenning, & Marino, 2005; Dahl, Aaserud, & Jensen, 1992; Schmidtbleicher & Buehrle, 1987) but none have been equated for training volume. As a result, the adaptations found with the training programmes in these studies may be a result of differences in volume, rather than the actual protocols performed.

Little research has compared the adaptive responses to two or more equi-volume resistance training protocols (Candow & Burke, 2007; Dahl et al., 1992; Harris, Stone, O'Bryant, Proulx, & Johnson, 2000; McBride, Triplett-McBride, Davie, & Newton, 2002; Schmidtbleicher & Buehrle, 1987). A recent study by Candow & Burke (2007) compared the effect of two equi-volume training protocols by manipulating the workout frequencies. One group performed two workouts (3 sets per exercise) per week while another performed three workouts (2 sets per exercise) per week. The authors noted improvements in lean tissue mass (2.2%), squat strength (28%) and bench press strength (18-30%) in both groups.

Training volume has been confirmed as a key variable underlying the acute training effect (Baker, 2001; Baker, Nance, & Moore, 2001; Crewther, Cronin, & Keogh, 2005; Dahl et al., 1992; Schmidtbleicher & Buehrle, 1987). A recent kinematic and kinetic study investigated the acute mechanical responses of three different workout schemes (hypertrophy, strength and power) (Crewther et al., 2005). Each exercise scheme was equated by workout duration with the power and strength protocols also equated by load volume. The high-volume hypertrophy scheme produced greater total forces, time under tension, work and impulses, compared with the low-volume strength and power schemes. These acute mechanical responses to resistance exercise provide the basic stimulus for power and strength adaptation (Crewther et al., 2005; Keogh, Wilson, &

Weatherby, 1999); therefore, examining the adaptive responses of equi-volume training protocols would provide a better understanding of underlying training stimulus for subsequent adaptations.

Strength and conditioning may benefit from research that compares different training programmes that are commonly used within practise. The use of the FB resistance training programmes has been superseded since the early 1960's by the SB protocols, which have become more popular for bodybuilders and advanced resistance trained athletes. However, many strength coaches and athletes continue to still use the FB training routines (Bird et al., 2005; W.J. Kraemer et al., 1992; Monteiro et al., 2009). The SB protocol provides a convenient training model because it allows individuals to train at a recommended frequency as well as the ideal intensity and volume while also providing adequate recovery. Furthermore, this protocol may enable individuals to train at a higher daily training intensity level compared with the FB protocol because isolating upper v lower body muscles on different days is potentially less energetically taxing than a FB training session (Kerksick et al., 2009). We are unaware of any studies that have compared FB and SB workouts of equi-volume in a strength-trained male population.

Training adaptation is mediated in part by the hormonal milieu and its influence upon skeletal muscle tissue (Crewther, Keogh, Cronin, & Cook, 2006). In particular, testosterone (T) and cortisol (C) play an important role in the training process by controlling long-term muscle growth and related changes in performance. Many training studies have compared the effects of different training protocols on resting T and/or C concentrations (Ahtiainen et al., 2005; Ahtiainen, Pakarinen, Kraemer, & Hakkinen, 2003;

McCall, Byrnes, Fleck, Dickinson, & Kraemer, 1999; M. C. Uchida, Aoki, Navarro, & Tessutti, 2006), but none of these studies have been equated for training volume.

The importance of training volume is also supported by cross-sectional studies that have found greater changes in T and C concentrations in response to high-volume hypertrophy programmes, but little to no changes in response to low to moderate volume, power and/or strength programmes (Crewther et al., 2006; Hakkinen & Pakarinen, 1993; W. J. Kraemer et al., 1998; McCall et al., 1999; Smilios, Piliandis, Karamouzis, & Tokmakidis, 2003). Furthermore, those schemes that have been equated by volume produced similar acute changes in T and C concentrations, irrespective of the number of repetitions performed and the load lifted (Crewther, Cronin, Keogh, & Cook, 2008; M.C. Uchida et al., 2009). These findings further emphasize that the training adaptations occurring may be related to differences in training volume, rather than the actual protocol performed.

Whilst the acute hormonal responses to exercise play a crucial role in mediating muscle growth in untrained populations, this may not be the case for trained populations. Strength-trained males have limited potential for inducing muscle growth and it appears that changes in resting hormones may play a role in moderating the performance gains with weight training (Ahtiainen, Pakarinen, Alen, Kraemer, & Häkkinen, 2003; Fry, Kraemer, Stone, & Warren, 1994; Häkkinen, Pakarinen, Alén, Kauhanen, & Komi, 1987). Once again, there is a lack of research examining the resting T and C responses to equi-volume training protocols in strength-trained males.

Overall, it appears that training volume is an important determinant of long-term resistance training adaptations and mediated, in part, by various mechanical and hormonal stimuli. Therefore, examining the adaptive responses of two equi-volume training protocols would provide a better understanding of the underlying stimulus for subsequent training and hormonal adaptations.

1.1 Purpose Statement

The overall aim of this thesis is to develop a better understanding of the resistance training stimulus and subsequent adaptations. First, literature that has examined the effects of training volume upon strength, body composition (e.g. free-fat mass, fat mass and muscle size) and hormones (i.e. T and C) will be reviewed. Second, the work from an experimental study will be presented. This experimental study will examine the effects of two equi-volume training protocols (FB and SB) upon strength, body composition and hormones in strength-trained males using a cross-over design. Third, a summary and conclusions based on the literature review and the experimental work will be provided. This will be followed by a section with practical applications, limitations of the experimental study and lastly recommendations for future research.

1.2 Aim

The overall objective of this thesis was to gain a greater insight into the comparative benefits of two commonly used resistance training protocols for increasing strength, body composition and resting hormone levels in strength-trained men. This was achieved by conducting a cross-over study in which all participants performed two equi-volume resistance training protocols (FB and SB) for a period of 4 weeks per protocol.

1.3 Hypothesis

It is hypothesized that both training protocols will experience significant improvements in strength, body composition and hormones; however, the improvements associated with the FB training protocol will be superior to that of the SB training protocol.

1.4 Significance

A direct benefit for the study population is to identify which resistance training protocol will maximise training adaptations during the 4-week training period. The results could also provide information on the most efficient method of training. Although the study focus is a strength-trained population, the training procedures may be applied to other populations (e.g. elderly, injured) to promote strength and other health-related gains. By examining the hormonal responses to the FB and SB training approaches, some insight may be gained regarding one of the underlying mechanisms for adaptation. Such information could also allow trainers and conditioners to prescribe resistance training more effectively and efficiently. Additionally, this study may provide the framework for further research in the area (i.e. equi-volume studies).

1.5 Notes to the reader

This thesis is presented as six major chapters; (1) an introduction of the topic and purpose of study, (2) a review that summarises the literature, (3) design and methodology outlining the experimental process, (4) results highlighting main findings of experiment, (5) discussion of main findings and, (6) summary of main findings and recommendations going forward. Please note that some information provided in this thesis may appear repetitive in parts, due to the formatting criteria used. However, this thesis fulfils the AUT Master of Health Science guidelines for thesis submissions.

1.6 Authorship Contribution

The contributions of the authors to the literature review and the experimental chapter within this thesis are as follows:

Literature review. Heke, T., (80%) Keogh, J (10%) Crewther, B., (10%)

Experimental chapter. Heke, T., (80%) Keogh, J (10%), Crewther, B., (10%)

2.0 CHAPTER TWO – LITERATURE REVIEW

The MEDLINE, Scopus, Sport Discus, Pubmed and CINAHL databases were used to locate previous original scientific investigations that examined the hormonal responses (particularly T and C) to resistance exercise. The search utilised the following key-words 'resting hormonal responses', 'equi-volume training', 'split body', 'full body', 'salivary testosterone' and 'salivary cortisol'. The names of popular authors associated with hormonal responses to resistance training were also utilised. Searches of relevant journal articles and reference lists obtained from articles were also conducted. Such combinations resulted in the inclusion of 45 original research articles addressing the effects of training volume (including equi-volume) upon performance (including strength, body composition and hormonal) using strength trained athletes.

2.1 Introduction

Coaches, trainers and instructors are continuously looking for ways to improve the force-generating qualities of the neuromuscular system, thereby improving functional ability during athletic tasks. Resistance training is widely recommended as a stimulus for inducing changes in muscle size and/or performance (e.g. strength, power and strength endurance), both in athletic and non-athletic populations (W.J. Kraemer et al., 2002). Resistance training is prescribed on the basis that the manipulation of the training variables (e.g. repetitions, sets, exercises, load intensity, and volume) produces acute stimuli that, over time, lead to long term adaptive changes in the neuromuscular system.

One of the confounding variables when prescribing resistance exercise is the effect of training volume (sets x repetitions x load). The importance of training volume is supported by the greater gains in muscle size and/or strength often found when performing more than two sets (per exercise) compared to one set (Marx et al., 1998; Paulsen, Myklestad, & Raastad, 2003; M. Rhea, Alvar, Ball, & Burkett, 2002). Moreover, modifying training volume was found to maximise increases in lean body mass and functional performance (Potteiger et al., 1995). Thus, it is possible that the adaptations occurring from resistance training may not merely be affected by the type of training performed, but also by the training volume, with one set per exercise not sufficient for maximal gains.

Many studies have compared the effects of different training protocols upon performance, body composition and/or hormones (Ahtiainen, Pakarinen, Alen et al., 2003; J. B. Kraemer, Stone, O'Bryant, & Conley, 1997; McBride, Blaak, & Triplett-McBride, 2003; Paulsen et al., 2003). Unfortunately, the majority of these studies have not equated for training volume between protocols, therefore the different responses may potentially reflect the differences in volume rather than inherent differences in the training approach.

This review will examine the general effect of; (1) training volume upon performance, (2) training volume upon the resting hormonal responses (specifically T and C), (3) equi-volume training upon performance, (4) equi-volume training upon the resting hormonal responses, (5) training volume and equi-volume training upon body composition responses and (6) saliva as a non-invasive tool for monitoring T and C. Such an analysis of the literature may enhance our understanding of the resistance training stimulus and how modifications in one variable (training volume) may affect different neuromuscular adaptations that are important to functional performance.

2.2 The effects of training volume on performance

The effects of training volume (i.e. sets performed per exercise) upon performance adaptation have been a topic of debate among coaches, trainers and scientists over many decades. Several training studies have examined the effects of resistance-training volume (i.e. multiple v. single sets) on different measures of performance (see Table 1). The most common recommendation from these studies is that multiple set training (three sets or more per exercise), rather than one single set, is the most effective method for improving training adaptation (J. B. Kraemer et al., 1997; McBride et al., 2003; Paulsen et al., 2003; M. Rhea et al., 2002).

Several theories have been proposed to explain why multiple sets of weight training elicit greater strength gains than single set programs (Seyle, 1974; Zatsiorsky, 1995). As an example, Seyle proposed the 'general adaptation syndrome' theory, which states that when an individual begins a weight training programme, an unaccustomed stress is presented to the neuromuscular system and the alarm phase begins. Once the neuromuscular system has been overloaded, it then adapts (resistance phase) to meet the stress, and if the stress is left unchanged for an extended time or is too strong, adaptation will cease (exhaustion phase) (Seyle, 1974).

Table 1. Studies examining the effects of training volume on performance.

References	Duration	Subjects	Training Protocol	Sets x Repetitions	1 RM Performance Changes (%)				
					Bench	Squats	Leg Press	Leg Ext.	Bicep Curls
Campos et al. 2002	8 wks, 2-3 sessions / wk	9 UT	Low repetitions	4 X 3 - 5 [c]	–	↑ 127	↑ 58.7	↑ 57.9	–
		11 UT	Int. repetitions	3 x 9 – 11[b]	–	↑ 78	↑ 24.6	↑ 52.6	–
		7 UT	High repetitions	2 x 20 – 28 [a]	–	↑ 78.9	↑ 17.7	↑ 52.9	–
Hass et al. 2000	13 wks, 3 sessions / wk	42 RT	1 set for 9 exercises	1 x 8-12RM	↑ 13.3	–	–	↑ 13.5	–
			3 sets for 9 exercises	3 x 8-12RM	↑ 16.1	–	–	↑ 11.8	–
Humburg et al. 2007	32 wks, 3 sessions / wk	22 UT	1 HRT	1 x 8 -12, 3 x 8 - 12	↑ 10.6	–	–	–	↑ 13.2
		22 UT	3 HRT	3 x 8 -12, 1 x 8 - 12	↑ 16.5	–	–	–	↑ 15.5
Kramer et al. 1997	14 wks, 3 sessions / wk	16 RT	SS to failure	1 x 8 – 12	–	↑ 12	–	–	–
		14 RT	MS to failure	3 x 10	–	↑25.6	–	–	–
		13 RT	SS & MS to failure	1 x 8 -12 and 3 x 10	–	↑ 22	–	–	–
McBride et al. 2003	12 wks 2 sessions / wk	9 UT	1 x LP & 1x BC	1 x 10RM, 6RM	–	–	↑ 33.5	–	↑ 9.7
		9 UT	6 x LP & 6 x BC	6 x 10RM, 6RM	–	–	↑ 53.5	–	↑ 20.5
Paulsen et al. 2003	6 wks, 3 sessions / wk	10 RT	3 UB & 1 LB	3 x 7RM, 1 x 7RM	↑ 10	↑ 13.5	–	↑ 14.5	–
		8 RT	3 x LB & 1x UB	3 x 7RM, 1 x 7RM	↑ 9.3	↑ 22	–	↑ 21.0	–
Rhea et al. 2002	12 wks, 3 sessions / wk	8 RT	1 set / exercise	1 x 4-10RM	↑ 19.5	–	↑ 25.3	–	–
		8 RT	3 sets / exercise	3 x 4-10RM	↑ 28.1	–	↑ 52.1	–	–

Key: a = 1 minute rest period; b = 2 minutes rest period; c = 3 minutes rest period; ↓indicates decrease; ↑ indicates increase; BC = biceps curls; 1 HRT = 1 set of heavy resistance training; 3 HRT = 3 sets of heavy resistance training; Int. repetitions = intermediate repetitions; Leg ext. = leg extensions; LP = leg press; MS = multiple sets to failure; RM = repetition maximum; RT = resistance trained; SS = single set to failure; UT = untrained; Wks = weeks.

Some studies did not find any differences between multiple- or single-set training approaches (Hass, Garzarella, De Hoyos, & Pollock, 2000; Humburg, Baars, Schroder, Reer, & Braumann, 2007), whilst the results of Campos et al. (2002) appeared to support the use of a low volume training protocol over medium and high volume training protocols. Further examination of this study revealed several reasons as to why the low volume protocol resulted in greater training adaptations compared to the other protocols. The low volume (4 sets of 3-5 RM) protocol received a three minute recovery period compared to the intermediate (3 sets of 9-11 RM) and high volume (2 sets of 20–28 RM) which had two and one minute/s rest, respectively. And the insufficient rest periods could have potentially led to fatigue as it does not appear to have been monitored or accounted for.

Previous literature (Hakkinen & Pakarinen, 1993; Häkkinen, Pakarinen, Alén, Kauhanen, & Komi, 1988; Rooney, Herbert, & Balnave, 1994) has differing opinions on the effects of fatigue on the acute and chronic performance. Hakkinen & Pakarinen (1993) suggested that intensive continuous muscular work utilised during heavy acute resistance training (high intensity / high volume protocol) would lead to a momentary decrease in performance of the neuromuscular system. In contrast Rooney, Herbert & Balnave (1994) reported that subjects who performed a medium to high volume training protocol without resting, experienced greater improvements in strength than those who trained with rest periods.

Closer inspection of the Hass et al. (2000) study identified some potentially confounding variables. For example, out of the forty-two subjects that participated in this study, thirty of them were females. Gender differences may have influenced the results of this study, with the absolute muscle strength of women being approximately 60% of the value of men (Heyward, Johannes-Ellis, & Romer, 1986) while other strength related gender differences included body mass, muscle fibre size, proportion of hip width to shoulder width and the proportion of body fat to body weight (Faigenbaum, 2000). As a further confounding variable, the participants in this study also performed an endurance/circuit type resistance training protocol which Glowacki et al. (2004) found resulted in decreased muscle fibre size, potentially impacting on strength gains negatively.

It is generally recognised that untrained subjects achieve greater resistance training adaptations, and on a faster timescale, than trained subjects (see reviews by Crewther et al., 2006; W.J. Kraemer & Ratamess, 2005). The neuromuscular system plays an important role in the strength increases observed in the early stages of adaptation to training (Rutherford & Jones, 1986). This was highlighted by improvements in motor unit recruitment, firing rate and synchronisation which took place predominately with untrained individuals (Rutherford & Jones, 1986).

The differences have been highlighted in studies comparing the adaptive responses to different training regimes in trained and untrained populations (J. B. Kraemer et al., 1997; McBride et al., 2003; Paulsen et al., 2003; M. Rhea et al., 2002). Further examination of Table 1 revealed that untrained populations produced strength gains in the range of between 15 to 49 % whereas trained populations produced gains of only 10 to 23 %. For example, Campos et al. (2002) performed an 8 week training study (using a three set protocol) in untrained men and reported large strength improvements for the squat (127%), leg press (59%) and leg extension (58%) exercises. Conversely, Hass and colleagues (2000) reported much smaller strength gains of 12% to 16% for their more experienced strength-trained subjects. These studies highlight the greater potential for strength changes in untrained subjects during the early phase of strength training, which are likely due to neural adaptations (e.g. motor unit recruitment and synchronisation).

Differential responses to the training stimulus may also be seen in the upper and lower body, for example, Paulsen et al. (2003) compared the effects of single set and multiple sets training programmes over six weeks using untrained males. One group performed three upper-body exercises and one lower-body exercise (3U1L) while the other performed three lower body exercises and one upper body (3L1U). Subjects used 7RM loads for all exercises and trained three times per week. After six weeks of training both groups increased their relative lower body strength, with the 3L1U group improving by 21% compared to improvements from the 3U1L group of only 14%. However, the relative upper body strength in the 3U1L (16%) and 3L1U groups (14%) were very similar after training. Based on their results, it was proposed that upper body muscles may have a lower stimulus threshold than lower body muscles, especially in the early adaptive phase of training (Paulsen et al., 2003).

Consequently, for untrained subjects, the upper-body muscles may exhibit strength increases through a lower volume of training per session, compared with lower-body muscles, especially during the early phase of resistance training. Therefore, single set training protocols (i.e. a lower training volume) for upper-body exercises might be sufficient for untrained subjects in the early phases of a strength training program, but this is unlikely to be the case for trained subjects who are already highly adapted to the training stimulus.

2.3 The effects of equi-volume training on performance

Equi-volume training protocols have been used by researchers and coaches to examine and compare the effectiveness of different resistance training protocols (Buford, Rossi, Smith, & Warren, 2007; Candow & Burke, 2007; McLester, Bishop, & Guilliams, 2000; Monteiro et al., 2009; M. R. Rhea et al., 2003). Keeping the volume constant while manipulating other training variables, essentially allows researchers to focus on other important variables such as training frequency or training load (See Table 2). For example, studies by McLester et al. (2000) and Candow & Burke (2007) examined the effects of manipulating weekly training frequency whilst other studies (Buford et al., 2007; Monteiro et al., 2009; M. R. Rhea et al., 2003) examined the effects of changing the daily and weekly training loads (periodised training) using different training protocols.

Table 2. Studies examining the effects of equi-volume training on performance.

References	Study Duration	Subject / Experience	Training Protocols; Exercise(s)	Sets x Repetition(s)	1 RM Performance Changes (%)			
					Bench	Squats	Leg press	Leg curls
Buford 2007	9 wks, 3 sessions / wk	9 UT	LP; 6 ex	3 x 8, 3 x 6, 3 x 4	↑24.3	–	↑ 85.3	–
		10 UT	DUP; 6 ex	3 x 8, 3 x 6, 3 x 4	↑17.5	–	↑ 79	–
		9 UT	WUP; 6 ex	3 x 8, 3 x 6, 3 x 4	↑ 24.5	–	↑ 98.3	–
Candow & Burke 2007	6 wks, 2 & 3 sessions / wk	15 UT	2 sessions / wk; 9 ex	3 X 10 at 60-90% of 1RM	↑ 17.9	↑ 27.3	–	–
		14 UT	3 sessions / wk; 9 ex	2 X 10 at 60-90% of 1RM	↑ 29.7	↑ 27.7	–	–
McLester et al. 2000	12 wks, 1 & 3 sessions / wk	9 RT	1 session / wk; 9 ex	3 x failure	↑ 10.6	–	↑ 22.3	↑ 25.2
		9 RT	3 sessions / wk; 9 ex	1 x failure	↑ 27.1	–	↑ 46.1	↑ 47.2
Monteiro et al. 2009	12 wks, 3 sessions / wk	9 ST	NP; 7 - 8 ex	3 x 8-10, 3 x 8-10, 3 x 8-10	↑ 5	–	↑ 7	–
		9 ST	LP; 7 - 8 ex	3 x 12-15, 3 x 8-10,3 x 4-5	↑ 2	–	↑ 16	–
		9 ST	NLP; 7 - 8 ex	3 x 12-15, 3 x 8-10,3 x 4-5	↑ 26	–	↑ 49	–
Rhea et al. 2003	15 wks, 3 sessions / wk	20 RT	LP; 1 ex	3 x 25, 3 x 20, 3 x 15	↑ 8	–	–	–
		20 RT	DUP; 1 ex	3 x 25, 3 x 20, 3 x 15	↑ 8.3	–	–	–
		20 RT	RLP; 1 ex	3 x 15, 3 x 20, 3 x 25	↑ 4.6	–	–	–
Simao et al. 2007	12 wks, 3 sessions / wk	10 RT	EX1; 10 ex	3 x 10 at 80% of 1RM	–	↑ 61	↑ 66.1	–
		13 RT	EX2; 10 ex	5 x 6 at 80% of 1RM	–	↑ 39	↑ 47.6	–

Key: LP = linear periodised; DUP = daily undulating periodised WUP = weekly undulating periodised; NLP = non linear periodised; NP = non periodised; RLP = reverse linear periodised; EX1 = experimental group 1; EX2 = experimental group 2; ↓ indicates decrease; ↑ indicates increase; RT = resistance trained; ST = strength trained; UT = untrained; 1 RM = one repetition maximum; wk = week; ex’s = exercises.

McLester et al. (2000) used strength-trained subjects to investigate whether training one day per week was as effective as training three days per week when the total weekly volume was equal. They reported that although both groups improved their strength performance, the high frequency group had greater improvements compared with the low frequency group in bench press (27% v 10%), leg press (46% v 22%) and leg curl (47% v 25%) exercises. Candow & Burke (2007) compared the training effects of two equal-volume protocols using untrained male and female participants. One group performed two workouts per week (3 sets per exercise) and the other performed three workouts per week (2 sets per exercise). The authors noted strength improvements in both groups for the squats (28%) and bench press (18-30%), with greater gains coming from three workouts per week protocol. Although these two studies used different populations (trained and untrained) they both highlighted the importance of training frequency. Whether there is an "optimal" training frequency to use before performance gains start to decline remains unclear.

Buford et al. (2007) performed a full body resistance training protocol using untrained subjects and reported strength gains of 17 to 25% for the bench press and between 79-91% for the leg press while another study by Rhea et al. (2002) which also used a whole body training protocol reported gains of 28.8% (bench press) and 55.8% (leg press) for trained subjects. These results suggested that, irrespective of the training status and the type of periodised programme used, the full body protocol appears to be just as effective as the split body protocols (Kerksick et al., 2009; Monteiro et al., 2009) at improving performance. However additional research was necessary to support these findings.

On closer inspection of our equal volume data (Table 2), it appears that the lower body exercises (i.e. leg-press, squats and leg extensions) experience substantially greater strength gains (27-98%) than the upper body exercises (17-29%). The large differences in the strength response between lower and upper body muscles may be related to their relative involvement during daily tasks, as proposed by Paulsen et al. (2003). For example, the quadriceps and hamstring muscles (lower body muscles) are antigravity and propulsive muscles, respectively, and exposed to a greater total load per day, as a result of carrying the body mass. In contrast, the pectoral or biceps muscles (upper body muscles) are not generally exposed to the same amount of work during daily activities. Consequently, the lower body may require a higher training volume per session to produce greater strength improvements compared with the upper body. These findings reflect the greater acute stress associated with the lower than upper body training on the metabolic and hormonal systems.

Periodised training has be seen as an effective way to optimise physiological strain and thereby produce greater long-term increments in muscle strength than a constant load training paradigm (Monteiro et al., 2009). One of the primary goals of periodised training programmes is to maximise the principle of overload and to ensure that the correct stress / recovery relationship occurred (M. R. Rhea et al., 2003). Howley & Franks (1997) stated that the principle of overload was a process by which the neuromuscular system experienced demands it was not accustomed to and, when faced with these increased demands, it adapted with increases in muscular function. Once the system had adapted to that demand or load, increases were no longer evident and eventually a plateau occurred and thus the use of periodisation to maximise the adaptation process by continually changing the load (M. R. Rhea et al., 2003).

2.4 The effects of training volume on the resting hormonal responses

Resistance exercise provides an effective stimulus for inducing chronic hormonal changes that combine with other factors (e.g. age, sex, training background) to induce muscle growth and related changes in performance (Ahtiainen, Pakarinen, Alen et al., 2003; Crewther et al., 2006; W.J. Kraemer & Ratamess, 2005; Linnamo, Pakarinen, Komi, Kraemer, & Hakkinen, 2005; McCall et al., 1999). The nature of these acute changes is determined by the different training variables or workout designs (e.g. exercise intensity, volume of exercise or training recovery periods between sets). Workouts which were high in volume, moderate to high in intensity with short rest intervals, and target large muscle groups tend to produce greater chronic hormonal elevations compared with low-volume, high intensity protocols using long rest intervals or smaller muscle groups (W.J. Kraemer & Ratamess, 2005).

Testosterone (T) and Cortisol (C) are two of the most commonly researched hormones in the field of strength and conditioning. T and C primarily have anabolic and catabolic actions on skeletal muscle respectively and play a major role in the promotion of muscle growth (hypertrophy) and / or improvement in performance resulting from resistance training.

T is generally considered the primary androgen, and is synthesised and secreted by the Leydig cells of the testes, via the hypothalamic-pituitary-gonadal axis (Crewther et al., 2006; W.J. Kraemer & Ratamess, 2005). Although the exact mechanisms for muscle growth are still unclear, T is thought to contribute to the remodelling of muscle protein by increasing protein synthesis (anabolic effect) and inhibiting protein degradation (anti-catabolic effect) (Crewther et al., 2006; W.J. Kraemer, 1992). Collectively, these effects account for the promotion of muscle hypertrophy by T. Other important hormones that appear to affect hypertrophy at various levels include growth hormone (GH), insulin like growth factors (IGF-1), Insulin, and Catecholamine. In addition, metabolic and mechanical stimuli are also key variables associated with the muscle growth process (Crewther et al., 2006).

Circulating androgens are predominately bound to the transport protein sex hormone binding globulin (SHBG). It is the unbound fraction or 'free testosterone' (free-T) that is biologically active (i.e. available to the tissues) and able to interact with the intracellular androgen receptors (AR). A change in SHBG concentrations may influence the binding capacity of T and the magnitude of free-T by acting directly with the AR in the target tissue (e.g. skeletal muscle) to mediate changes in the function of muscle cell via enhanced protein synthesis (Kraemer & Ratamess, 2005). T may also indirectly contribute to protein accretion by stimulating the release of other anabolic hormones, such as growth hormone (Crewther et al., 2006).

C is the main member of a family of steroid hormones called glucocorticoids and is predominantly synthesised and secreted from the adrenal cortex, via the hypothalamic–pituitary adrenal (HPA) axis (Crewther et al., 2006). It is the primary catabolic hormone, where it contributes to the degradation of muscle protein (W.J. Kraemer & Ratamess, 2005). C also stimulates lipolysis in adipose cells and decreases protein synthesis in muscle cells resulting in greater releases of lipids and amino acids into circulation. C accounts for almost 95% of all glucocorticoid activity with approximately 10% of circulating C being free, while 10-15% is bound to albumin and ~75% is bound to corticosteroid-binding globulin (W.J. Kraemer & Ratamess, 2005).

The acute hormonal responses to resistance exercise may be important for inducing early phase adaptive changes in untrained populations, but it appears that chronic changes in the hormones may have greater importance for inducing adaptive performance changes in subjects with a resistance training background (Fry et al., 1994; Hakkinen & Pakarinen, 1991; McCall et al., 1999; Ostrowski, Wilson, Weatherby, Murphy, & Lyttle, 1997). This review will focus on chronic or resting changes in the T and/or C concentrations as a result of resistance training.

The long-term effects of training on the resting concentrations of T and C have been studied extensively (see Table 3). Strength-trained athletes were found to exhibit a greater T response than non-athletes (Cadore et al., 2009) while other training studies (Ahtiainen, Pakarinen, Alen et al., 2003; Tremblay, Copeland, & Van Helder, 2004) also discovered that strength-trained athletes exhibited greater levels of resting T compared to the non-strength-trained athletes. The resting C concentrations were found to generally reflect a long term resistance training stress (Ahtiainen, Pakarinen, Alen et al., 2003; Ostrowski et al., 1997) in the strength-trained population. Although strength-trained populations have limited potential for inducing additional muscle growth, they can still exhibit large changes in resting hormones (Ahtiainen, Pakarinen, Alen et al., 2003; Ostrowski et al., 1997; M. C. Uchida et al., 2006).

Ahtiainen et al. (2003) investigated the hormonal and neuromuscular adaptations to a 21-week strength training programme using eight non athletes (NA) and eight strength athletes (SA). The effects of training on performance (strength and muscle size) and hormones (T and C) were monitored throughout the training period with the NA and SA training groups improving in strength (21% v 5.6%) and muscle size (3.9% v -

1.8%) respectively. In the same study T concentrations increased during the initial stages of the training period (first 14 weeks) for the SA due to an increase in training volume. However, the remaining training period saw a decrease in the training volume, which also resulted in a decrease in the T concentrations. These findings were similar to previous research (Häkkinen et al., 1987) which found that the T concentrations increased and decreased relative to the training volume and/or intensity.

Table 3. Studies examining the effects of training volume on resting hormonal responses.

References	Study Duration	Subjects / Experience	Training Protocol	Sets x Repetitions	Hormone (% change)		
					Testo	Free Testo	Cortisol
Ahtiainen et al. 2003	21 wks, 2 sessions / wk	8 SA	MR, 3 ex’s	8 x 12 RM	↑13	↑35.2	↑65.7
		8 Non A	FR, 3 ex’s	8 x 12 RM x 15%	↑21.3	↑35.6	↑94.3
Ahtiainen et al. 2005	24 wks, 4 sessions / wk	13 SA	5 x 10RM + 4 x 10RM	5 x 10 RM + 4 x 10 RM	↓0.4	↑7.6	↑16
			4 x 10RM + 3 x 10RM	4 x 10RM + 3 x 10RM [b]	↓1.7	↓4.1	↑13.3
Izquierdo et al. 2006	16 wks, 2 - 3 sessions / wk	14 SA	TF; 8 ex’s	3 x 6 – 8 RM	↓3.1	N / A	↑12.5
		15 SA	NTF; 8 ex’s	3 x 6 – 8 RM	↑13.8	N / A	↓13.8
		13 SA	Control	No exercise	↑13.8	N / A	↓17.5
McCall et al. 1999	12 wks, 2-3 sessions / wk	11 RT	8 ex’s; 3 x 10RM	3 x 10 RM [a]	↓2.2	N / A	↓22
		8 RT	Control	No exercise	N / A	N / A	↓8.4
Ostrowski et al. 1997	10 wks, 4 sessions / wk	9 RT	LV, 24 ex's	3 sets / ex / week	↑17.2	↑75	↓13.3
		9 RT	MV, 24 ex's	6 sets / ex / wk	↑37.8	↑72.7	↑96.6
		9 RT	HV, 24 ex's	12 sets / ex / wk	↓37.3	↓57.1	↓20.7
Uchida et al. 2006	8 wks, 4 sessions / wk	6 RT	MS; 6 ex’s	4 x 10	↑12.5	N / A	↓31.2
		6 RT	TS; 3 ex’s	3 x 10	↓12.1	N / A	↓69.8

Key: [a] = 1 minute rest period; [b] = 5 minutes rest period; ex / wk = exercises per week; ↓ indicates decrease; ↑ indicates increase; Free Testo = free testosterone; FR = forced repetitions; HV = high volume; LV = low volume; MR = maximal repetitions; MS = multiple sets; MV = moderate volume; N / A = not applicable; Non A = non athletes; NTF = not to failure; RM = repetition maximum; RT = resistance trained athletes; SA = strength athletes; Subjects / exp = subjects / experience; Testo = testosterone; TF = training to failure; TS = tri sets; wks = week.

The T to C (T/C) ratio has been used as an indicator of the anabolic - catabolic status of skeletal muscle during resistance training (W.J. Kraemer & Ratamess, 2005). Kraemer et al. (1988) used the T/C ratio as an indicator of changes in the body's anabolic-androgenic activity, for example, an increase in T and/or a decrease in C would indicate a potential state of anabolism. However, due to the inconsistent nature of the hormonal process this ratio only appears (at present) to be an indirect measure of the anabolic - catabolic properties of skeletal muscle (W.J. Kraemer & Ratamess, 2005). A greater understanding of this process needs to be appreciated by researchers before a clear direction is established.

Some training studies have found no significant group changes in the T/C ratio, but on an individual level the changes that occurred were found to be positively related to the performance changes of each individual (Ahtiainen, Pakarinen, Alen et al., 2003; Alen, Pakarinen, & Hakkinen, 1988; Hakkinen & Pakarinen, 1994). For example, Ahtiainen et al. (2003) performed a 21-week strength training programme using NA and SA respectively and noticed that, although the T/C ratio did not change significantly during the training period, there were performance improvements in strength (21% v 3.9%) and muscle size (5.6% v -1.8%).

Gorostiaga et al. (1999) performed a six week study examining the effects of heavy resistance training on the T/C ratio in adolescent males. An increase in the T/C ratio was accompanied by considerable gains in the leg (13%) and arm (23%) strength while a periodised high-volume training programme by Marx and colleagues (2001) was found to produce a significantly greater increase in the T/C ratio than a low-volume, single set programme. Thus, a more anabolic balance would seem beneficial to muscle performance. Collectively, these findings suggest that training volume can modify the hormonal environment and that such changes are associated with improvements in muscle size and/or function.

Studies by Izquierdo et al. (2006) and Kraemer et al. (1995) examined the effectiveness of high intensity training on the strength and power as well as T and C concentrations. Izquierdo et al. (2006) performed a 16-week high intensity training programme using 42 strength trained subjects. The authors reported that training to failure resulted in a substantial decrease in resting T and an increase in resting C concentrations (See Table 3), whilst not training to failure elevated T concentrations and reduced resting C. Based on these findings this study supports previous research that found that the resting C concentrations generally reflected a long term resistance training stress (Ahtiainen, Pakarinen, Alen et al., 2003; Ostrowski et al., 1997).

2.5 The effects of equi–volume training on the resting hormonal responses

Many training studies that have compared the effects of different resistance training protocols upon muscle performance and resting hormones (Abe et al., 2003; Ahtiainen et al., 2005; Bird et al., 2005; Buford et al., 2007; Candow & Burke, 2007; Dahl et al., 1992; Schmidtbleicher & Buehrle, 1987) but none have been equated for training volume. To the best of my knowledge, no previous training studies have investigated the effects of equi-volume training on the resting T and C concentrations. Therefore, the varying adaptations found with the different training programmes may at least partially reflect differences in volume, rather than the actual protocols performed. Thus, further research examining and comparing the effects of two or more equi-volume training protocols on the resting concentrations of T and C would appear necessary to advance our understanding of how changes in the basal hormonal levels affects the adaptation process.

2.6 The effects of resistance training on body composition

Many studies have investigated the effects of resistance training on body composition in strength trained male (Argus, Gill, Keogh, Hopkins, & Beaven, 2010; Buford et al., 2007; McLester et al., 2000; Morgan & Callister, 2010; Schiotz, Potteiger, Huntsinger, & Denmark, 1998) and untrained male (J. B. Kraemer et al., 1997; McBride et al., 2003).

Following a 6-week reduced volume maintenance phase (off season) Argus et al. (2010) investigated the effects of a four-week pre-season resistance training protocol on strength, power, body composition and fatigue in professional rugby union players. All players trained 5 days per week with each training sessions consisting of either resistance training sessions (45-60 minutes in duration), aerobic conditioning (20-60 minutes), anaerobic conditioning (45-60 minutes) or rugby specific skills. The players performed between 4 to 10 exercises per resistance training session depending on the goal of each session (hypertrophy, strength or power). Although this study was only four weeks in duration they still managed to find an improvement in fat free mass (FFM) (2.2 kg), flexed upper arm girth (0.6 cm) and mid thigh girth (1.9 cm), while there was also a reduction in the sum of eight skin-folds (-11.0 mm).

Another study performed by Morgan and Callister (2010) investigated the effects of a preseason (fourteen weeks) intervention on anthropometric characteristics (i.e. fat mass, muscle mass and percent body fat) of fifty-seven (29 backs and 28 forwards) semi-professional rugby league players. Over the preseason, both backs ($p < 0.01$) and forwards ($p < 0.001$) reduced fat mass (FM) and increased muscle mass (backs, $p < 0.001$; forwards, $p < 0.001$). Furthermore, between-group analyses indicated that forwards experienced significantly greater reductions in some skin-fold sites (triceps, subscapular and abdominals); FM and overall percent body fat (% BF) than backs. These two studies highlight the importance of training volume for highly trained populations, for example, the study by Argus et al (2010) was only conducted over four weeks, but the high volume of training allowed for potentially greater strength and body composition adaptations to take place.

McLester et al. (2000) compared the effects of performing a high frequency with a low frequency resistance training protocol on strength and body composition using an equi-volume (weekly) protocol. They found that both groups had body composition improvements although the high frequency group tended to have greater lean body mass (LBM) improvements (7.6 % v 1.4 %), greater reductions in the sum of skin-folds (9.5 mm v 7 mm) and % BF (7.8% v 5.8%) compared to the low frequency group. This study showed that greater body composition improvements were associated with a high frequency and moderate volume training protocol. Buford et al. (2007) had similar % BF improvements after a nine week equal volume training period with reductions in % BF for the linear periodised (5%), daily undulating (6.6%) and weekly undulating (3.9%) protocols observed.

Kramer et al. (1997) compared single sets (SS) to failure resistance training protocols with multiple sets (MS) to failure protocols. While there were greater strength improvements associated with the MS (25.6%) compared to the SS (12%) protocol, these strength improvements did not result in any significant changes in body mass (BM), % BF or LBM. Although there were no significant changes, the MS group did improve BM by 1.95% and LBM by 1.7% after the 10 week training period. These results show that a possible trend exists whereby performing a high volume / high intensity protocol will produce greater body composition benefits than a low volume / high intensity protocol.

2.7 Monitoring of Sal-T and Sal-C during resistance training

Blood sampling is the most commonly used method of assessing hormones in sport and exercise; however, in recent years, saliva has become increasingly important as a medium for steroid hormone determination (Cadore et al., 2009; Crewther, Lowe, Ingram, & Weatherby, 2010; Gozansky, 2005; M. R. McGuigan, Egan, & Foster, 2004).

Saliva offers several benefits for athletes such as being less stressful to collect than blood (e.g. venepuncture) and readily available in reasonable quantities. In addition, saliva offers the possibility of collecting multiple samples and in a relatively short time interval, especially where blood collection is either undesirable or difficult to obtain (Lewis, 2006; Vining, McGinley, & Symons, 1983). Strong correlations (r = 0.97) have been demonstrated between the salivary and blood levels of C (Vining, McGinley, & Symons, 1983). Another study by Vittek et al, (1985) also reported moderate to strong correlations (r = 0.70-0.87) between the T measures in saliva and blood. Thus, salivary hormones provide valid measurements of the blood hormones.

Essentially, most (95-99%) of the steroid hormones are bound to carrier proteins in blood, such as sex hormone binding globulin (SHBG), corticosteroid-binding globulin (CSBG) and albumin (Kaufman & Lamster, 2002). However, it is the small (1-5%) unbound or free hormone that is generally considered the biological active hormone, or the portion that initiates the biological response at the target tissue. This is important because only the free steroid crosses the cells of the salivary glands (Dabbs, 1990) therefore, saliva provides a convenient fluid for monitoring (indirectly) the biological active free hormone. Salivary T and C have been shown to be a valid reflection of blood hormones during exercising conditions (Crewther et al., 2008; Crewther, Lowe et al., 2010; Gozansky, 2005) so could be used as a non-invasive tool for monitoring exercis*e* and training effects. In fact, salivary T and C may provide a more sensitive measure of exercise and training stressors than blood hormones, offering further benefits for monitoring athletes (Cadore et al., 2009; Crewther, Lowe et al., 2010; Gozansky, 2005; M. A. McGuigan & Kane, 2004; Vining, McGinley, Maksvytis, & Ho, 1983).

Many studies have used salivary hormones (including Sal-T and Sal-C) to assess the hormone activity in athletes. For example, Argus et al. (2009) and Crewther, Cook, Lowe et al. (2010) collected saliva samples to compare the effects of resistance training on the upper and lower body muscle groups. McGuigan Egan & Foster (2004) examined and compared the effects of low and high intensity training using Sal-C only. Beaven, Cook & Gill (2008) utilised four different training protocols (with various training intensities) to identify individual Sal-T concentrations (minimum and maximum) in trained rugby players, and then examined what effects these hormonal concentrations had on performance. A similar study by Crewther et al. (2008) used the squat exercise to examine and compare the effects of performing three different loading schemes (hypertrophy, strength and power) on performance and hormonal (T and C) concentrations.

Argus et al. (2010) assessed the changes in strength, power and hormones during a 13 week competitive rugby season performed by elite rugby players. Moderate increases in Sal-T (54%) and Sal-C (97%) were observed during this period while an improvement in lower body strength (8.5%) but not the upper body (-1.2%) also occurred. Crewther, Cook, Lowe et al. (2010) examined the effects of short-cycle sprints on power, strength and salivary hormones using elite rugby players. Elevated Sal-T concentrations were associated with a positive lower body training environment, compared with the upper body, in which no change in hormonal levels were found. The authors attributed the resultant improvements in bench press (2.8%) and box squats (2.6%) strength to the observed changes in absolute or relative hormone concentrations during the training period.

McGuigan et al. (2004) performed an acute training study using the squat and bench press exercises to measure the Sal-C responses to a high (6 x 10 repetitions at 75% 1RM) and low (3 x 10 repetitions at 30% 1RM) intensity training protocol. They found that there was a significant increase (97%) in Sal-C concentrations immediately following the high intensity protocol while there were no changes after the low intensity. These findings support other research that suggests C to be a physiological mechanism in response to stress (Crewther et al., 2006; W.J. Kraemer & Ratamess, 2005; M. Viru, Litvinova, Smirnova, & Viru, 1994).

In the study by Beaven, Cook & Gill (2008), sixteen amateur rugby players performed four different resistance training protocols: 4 x 10 repetitions (reps) at 70% 1RM with 2 minutes (mins) rest between sets; 3 x 5 reps at 85% 1RM with 3 mins rest; 5 x 15 reps at 55% with 1 mins rest and 3 x 5 reps at 40% 1RM with 3 mins rest. Eight players then performed 3 weeks (training period) using their Sal-T maximum (max) protocol while the other eight performed their Sal-T minimum (min) protocol. After the 3 weeks training period all participants were retested and then both groups crossed over and performed the other protocol. All 16 players showed significant improvements in bench and leg press while performing the Sal-T max protocol while at least 75% of the athletes showed either no change or a significant decline in performance after the Sal-T min protocol.

2.8 Summary and conclusions

Overall, it appears that resistance training volume is the one of the most important determinants of the subsequent improvements in muscle strength and hormones in untrained and trained populations. Therefore, examining the adaptive responses of equi-volume training protocols would provide a better understanding of the underlying (e.g. hormonal) stimulus and how to maximise resistance training adaptations. There are no previous training studies that have attempted to investigate the effects of equi-volume training protocols upon performance and hormones in strength-trained males. Therefore the purpose of this study is to examine the effects of two equi-volume training protocols (FB and SB) upon strength, body composition and hormones in strength trained males during two 4-week training periods using a cross-over study design.

3.0 CHAPTER THREE - DESIGN AND METHODOLOGY

3.1 Experimental design

A randomised, crossover design was used to test the research hypotheses. Two parallel training groups were matched by age, height and body mass, and assessed for muscle strength, body composition and hormones before and after two 4-week training periods. Each 4-week period of training was separated by an 8-week washout period. The cross-over design allowed for a within-subject analysis (where each subject acted as their own control), increasing the ability to detect small differences between training approaches due to greater statistical power.

3.2 Participants

A group of 26 strength-trained males initially volunteered to participate in this study. Two subjects were removed from the study due to non-compliance with the experimental protocols or through injury and thus, data for 24 subjects were analysed. The mean (SD) age, height and mass of the participants were 29.8 (6.8) years, 179.5 (7.9) cm and 92.9 (12.2) kg, respectively. All subjects had at least two years of resistance training experience (3-4 times per week) and were considered healthy, but with no current injuries or health problems that could affect their participation. Before the study commenced, subjects were given an information sheet (Appendix 1) which outlined all the relevant material and procedures for this study. Each subject also had the risks of the study explained to them and signed an informed consent prior to participation (Appendix 2). All subjects maintained relatively similar training regimes during the two training and one washout phase of this study, nonetheless, some degree of between-subject variations potentially existed. The use of a cross-over study design minimised the possible effect of this between-subject variation on the outcome measures, meaning that the comparison of the two resistance training protocols would have been largely unaffected. Ethical approval was given by the Auckland University of Technology Human Subjects Ethics Committee (Ethics Application, 09/125).

3.3 Equipment

Subjects performed all their resistance training and assessments of the upper body (bench press) and lower body (Squats) extremities using standard gym equipment, comprising of squat racks, dumbbells, barbells, free weights and machines (Fitness Works, NZ). Body composition was assessed using a stadiometer (Seca 214, Medshop, NZ), electronic scales (BWB 800, Wedderburn - Australia) and skinfold measurements were collected using body fat callipers (Holtain Ltd, Crymych, UK) and a tape measure (Lufkin, Executive Thinline, USA). All resistance training exercises and assessments (strength, body composition and salivary hormones) were performed and collected at Zero Limits gymnasium in Te Awamutu.

3.4 Training Procedures

The subjects were randomly allocated into one of two groups that each used different training protocols: the full body (FB) protocol, which exercised all muscle groups during each training session, and the split body (SB) protocol, which only exercised a subset of the muscle groups during each session. The matched-group demographics were FB (age, 30.3 ±8.2; height, 179.7 ±5.9; mass, 94.0 ±14.3) and SB (age, 29.1 ±8.3; height, 180.1 ±8.3; mass, 92.0 ±10.8). Subjects performed either the FB or SB protocol during the first 4-week training period, followed by an 8-week wash-out period before the second 4-week training period (See Figure 1).

A counterbalanced design was used so that each group had the same number of subjects (n = 13). Both groups trained 3 days per week (Monday, Wednesday and Friday), between the hours of 4 – 6pm and performed the same number of sets and repetitions for each muscle group across each training week (weekly equi-volume).

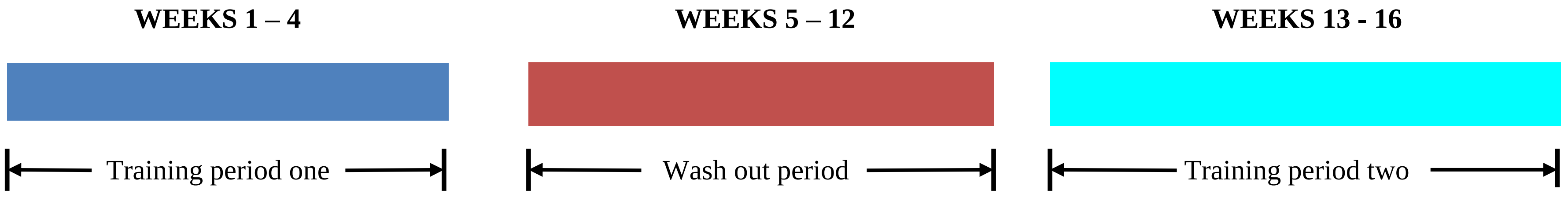

Figure 1: Experimental study training period. Training period one = weeks 1 - 4 (four weeks in duration); wash out period = weeks 5 – 12 (eight weeks in duration); training period two = weeks 13 – 16 (four weeks in duration). Total weeks of training study = 16 week.

All subjects performed their 8 repetition maximum (8RM) for all exercises with rest periods of 60 seconds between sets and 90 seconds between exercises and sets. The exercises, exercise order and loading parameters (i.e. sets and repetitions) in each of the FB and SB training protocols are provided in Table 4 and Table 5. The resistance exercises performed during the experimental training period are also illustrated in Figure 2.

Both groups performed a total of 51 sets of exercises per week with FB performing three identical training sessions of 17 sets of exercises per day, while SB performed 21 sets on Monday, 15 on Wednesday and 15 on Friday. The FB training protocol required subjects to perform exercises for all seven muscle groups evenly over each of the three weekly training sessions. The major muscle groups (legs, chest and back) all performed three sets of eight repetitions while the minor muscle groups (shoulder, biceps, triceps and calves) all performed two sets of eight repetitions. FB had a 48 hour recovery period between consecutive training sessions. The SB training protocol required subjects to perform all exercises for specific muscle groups in one training session per week. For example, the chest, shoulder and biceps exercises were performed on the Monday, legs on Wednesday and back and triceps on Friday. SB had at least five days rest and recovery between consecutive muscle training sessions.

Before each training session, subjects performed a standardised warm-up comprising of light jogging, stretching and basic lifting exercises using light loads. Retesting to re-establish loading parameters for each week was performed after the warm up had been completed. All subjects were reminded to perform as close to their 8RM for all exercises during all sessions.

Table 4: Full body (FB) resistance training workout.

Training Protocol 1: Full Body (FB) workout				
Monday	Tuesday	Wednesday	Thursday	Friday
Legs		Legs		Legs
Squat 3 x 8		Leg curls 3 x 8		Leg press 3 x 8
Chest		Chest		Chest
Flat bench press3 x 8		Decline DB press3 x 8		Incline DB press 3 x 8
Back		Back		Back
Bent over row 3 x 8		Lat pulldowns 3 x 8		Cable row 3 x 8
Shoulder	REST DAY	Shoulder	REST DAY	Shoulder
DB shoulder press 2 x 8		DB shoulder press 2 x 8		DB shoulder press 2 x 8
Biceps		Biceps		Biceps
DB supination curls 2 x 8		DB supination curls 2 x 8		DB supination curls 2 x 8
Triceps		Triceps		Triceps
Close grip BP 2 x 8		Close grip BP 2 x 8		Close grip BP 2 x 8
Calves		Calves		Calves
Standing calf raises 2 x 8		Standing calf raises 2 x 8		Standing calf raises 2 x 8

Key: All exercises will be performed as (sets x repetitions); DB shoulder press = dumb-bell shoulder press; DB supination curls = dumb-bell supination curls; close grip BP = close grip bench press.

Table 5: Split body (SB) resistance training workout.

Training Protocol 2: Split Body (SB) Workout				
Monday	Tuesday	Wednesday	Thursday	Friday
Chest Flat bench press 3 x 8 Decline DB press 3 x 8 Incline DB press 3 x 8 Shoulder DB shoulder press 6 x 8 Biceps DB supination curls 6 x 8	REST DAY	Legs Squat 3 x 8 Leg curls 3 x 8 Leg press 3 x 8 Calves Standing calf raises 4 x 8 Seated calf raises 2 x 8	REST DAY	Back Bent over row 3 x 8 Lat pulldowns 3 x 8 Cable row 3 x 8 Triceps Close grip BP 6 x 8

Key: All exercises will be performed as (sets x repetitions); DB shoulder press = dumb-bell shoulder press; DB supination curls = dumb-bell supination curls; close grip BP = close grip bench press.

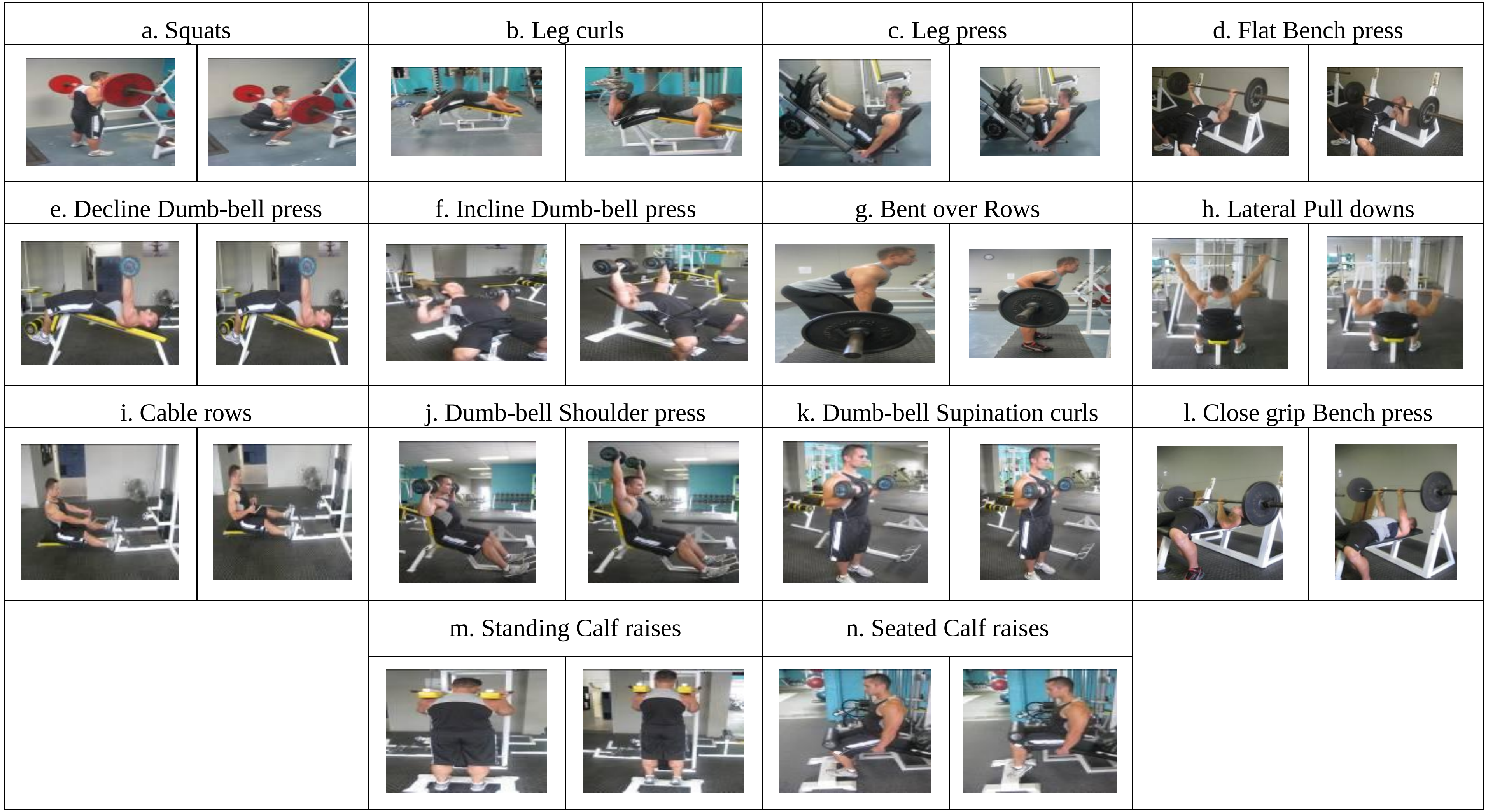

Figure 2: All resistance exercises used during the experimental training period. a. squats; b. leg curls; c. leg press; d. flat bench press; e. decline dumb-bell press; f. incline dumb-bell press; g. bent over rows; h. lateral pull downs; i. cable rows; j. dumb-bell shoulder press; k. dumb-bell supination curls l. close grip bench press; m. standing calf raises; n. seated calf raises.

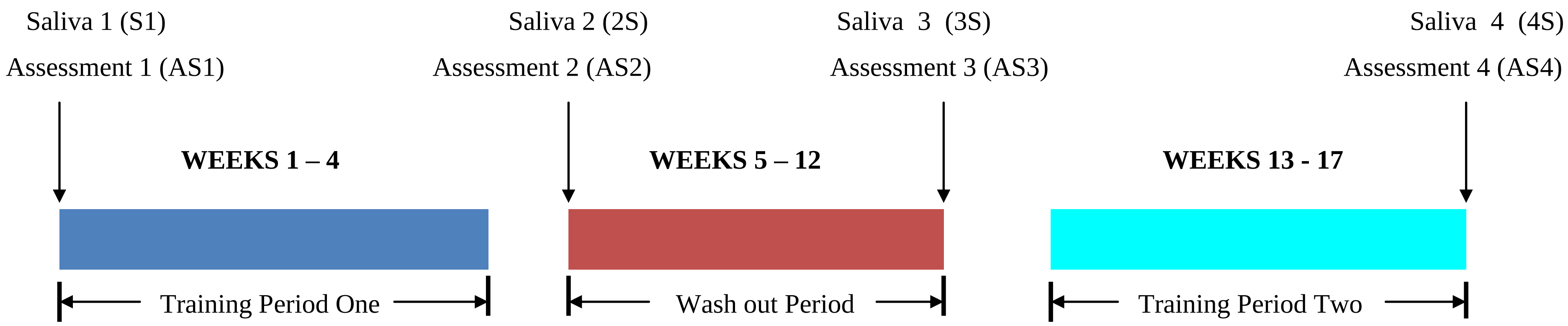

Figure 3: Saliva samples and assessment time-points. Total weeks of training study = 16 weeks. S1 / AS1 = pre training saliva sample / assessment taken prior to the start of training period 1; S2 and AS2 = saliva and assessment 2 taken at the start of the wash-out period; S3 and AS3 = saliva and assessment 3 taken at the end of the washout period; S4 and AS4 = saliva and assessment 4 taken at the end of training period 2.

3.5 Assessment Procedures

The timing of the hormonal, body composition and strength assessments are highlighted in Figure 3. The first assessment was performed on the Friday prior to the start of training period one (Week 1), the second was taken on the Monday at the start of the washout period (Week 5), the third, on the Friday at the end of the washout period (Week 12), with the final assessment performed on the Monday the week after the end of training period two (Week 17). Prior to each assessment, subjects were instructed to sit down for 15 minutes to ensure a resting saliva sample was taken, after which the body composition data were collected (height, body mass, sum of 4-skinfolds) and the one repetition maximum (1RM) lifts for the upper body (Bench press) and lower body (Squats) exercises measured. All participants were instructed to continue with their normal training and supplement regimes during the eight week washout period. All assessments were performed under the guidance of the researcher and his research assistant.

3.6 Salivary hormonal assessment

Saliva samples were collected to determine the hormonal (Sal-T and Sal-C) responses to both training protocols. Subjects were required to deposit saliva samples (~1 mL) into a 2-mL sterile container (Labserve, NZ), which were then stored at -20°C until assay. Hormones were measured using enzyme-linked immunoassays (Salimetrics, USA), according to the kit instructions. Strong correlations have been demonstrated between the salivary and blood levels of C (r = 0.97) (Vining, McGinley, Maksvytis et al., 1983) and moderate to strong correlations for T (r = 0.70-0.87) (Vittek et al., 1985). Thus, salivary hormones provide valid measurements of the blood hormones.

The secretion of T and C have been shown to exhibit a circadian rhythm with the greatest concentrations found early in the morning before decreasing throughout the rest of the waking day (Goldman et al., 1985; W.J. Kraemer et al., 2001). Consequently, all participants were required to perform their resistance training, saliva sampling and assessment sessions during the hours of 4 - 6 pm. Participants were required to sit down and perform no exercise for 15 minutes prior to taking a resting saliva sample. In addition, they were advised to avoid eating any coarse textured food, brushing their teeth, drinking coffee or other hot drinks two hours prior to supplying saliva samples (Cook, 2002). They were also required to use a training and nutrition diary throughout the training period to document important training information which was collected by the researcher at the end of the study. All the training and nutrition diary information was checked for within-subject consistency across the training phases for all individuals, but the results of this analysis are not presented.

3.7 Body composition assessment

Body composition was assessed with subjects wearing shorts, a shirt and socks. A wall-mounted stadiometer was used to determine subject height to the nearest 0.1cm. Body mass was measured to the nearest 0.1kg using an electronic scale (BWB 800, Wedderburn - Sydney Australia). The student, qualified with the International Society for the Advancement of Kinanthropometry (ISAK) level one, collected four skinfold measurements with body fat callipers (Holtain Ltd, Crymych, UK) and a tape measure (Lufkin, Executive Thinline, USA) using the methods described elsewhere (Withers, Craig, Bourdon, & Norton, 1987). The sum of skinfolds was converted to a body fat percentage using a formula (Durnin & Rahaman, 1967). Fat-free mass was then calculated by subtracting the fat mass from total body mass. They were given the opportunity to have a support person present if they wished and to be assessed in a private room at the assessment location.

The intra-tester technical error of measurement (TEM) requirement for ISAK level one accreditation is less than 7.5% for skinfolds and less than 2.5% for girths. The TEM (%) for our four skinfold measurements were subscapular (2.15%), iliac crest (1.69%), biceps (3.05%) and triceps (2.47%) respectively.

3.8 Strength assessment

Lower (parallel squat) and upper (bench press) body strength were determined by the maximum amount of weight that could be lifted once, or one repetition maximum (1RM). The assessment procedures were similar to that used previously (McBride et al., 2002). For safety reasons, a standard warm-up was performed before each assessment, involving stretching and basic exercises using light loads. After the warm-up, subjects stood under a barbell, with their feet positioned at predetermined positions which were marked by tape (approximately shoulder width apart). Their hands gripped the barbell and held it firmly making sure to rest it on the upper back and shoulders (Figure 4a). Subjects then squatted down using a controlled movement on the eccentric phase, with a slight pause at the bottom position, before explosively pushing up on the concentric phase. The lift was deemed successful when the subject lowered themselves to a knee angle not lower than 90º to the floor (Figure 4b) and stood upright without assistance (Figure 4c). Failure to complete a successful lift resulted in it being repeated after a 3 – 5 minutes rest period. Two spotters stood at each end of the barbell ready to assist the subject if and when required.

a **b** **c**

Figure 4: Different phases of the parallel squat exercise. **a.** Beginning position; **b.** Lowest depth reached with knees no lower than 90º to the floor; **c.** Finishing position

For the bench press, subjects lay supine on a flat bench and extended arms out to reach the barbell, which was marked by tape at a predetermined position (approximately shoulder width apart). The subject then lowered the barbell during the eccentric phase (to lightly touch the chest), with a slight pause at the bottom position, before explosively pushing the load up during the concentric phase. The assessment was deemed successful if the subject lowered the barbell to the required depth (see Figure 5a and 5b) and fully extended the arms with assistance (Figure 5c). The bench press trial was deemed incorrect if the subject bounced the barbell off ones chest; raise their buttocks off the bench, or lifted any foot off the ground. Failure to complete a successful lift resulted in it being repeated after a 3 – 5 minutes rest period.

a **b** **c**

Figure 5: Different phases of the bench press exercise**. a.** Beginning position; **b.** lowest depth reached; **c.** Finishing position.

3.9 Statistical analyses

Dependent t-tests were used to analyse the within-group changes in the outcome variables, while independent t-tests were used to analyse the between-group differences in the change scores of these variables. The change scores were calculated as the pre-post difference in each outcome measure for each participant. Data that did not meet statistical assumptions were log-transformed before analysis and then back-transformed into their original units. The level of significance in this study was set at $p \leq 0.05$. All values were reported as mean ± *SD*.

4.0 CHAPTER FOUR – RESULTS

Table 6 shows the strength and body composition results for the FB and SB training protocols. Absolute values are presented, along with the percentage (%) changes (from pre to post) for each variable. The salivary hormonal results are presented in Table 7, with the absolute values presented along with the percentage (%) changes for the FB and SB training protocols.

4.1.0 Strength changes

Both the FB and SB protocols resulted in significant improvements in strength (see Figure 6 and 7). Specifically, significant increases in squat (SQ) (FB, $p < 0.001$; SB, $p < 0.001$) and bench press (BP) (FB, $p < 0.001$; SB, $p < 0.001$) strength were observed. However, the magnitude of the strength improvements in the SQ (FB, 9.1kg ± 4.8; SB, 7.3kg ± 4.8) and BP (FB, 7.3kg ± 4.1; SB, 6.5kg ± 3.6) exercises were not statistically different between the two training protocols ($p = 0.160 – 0.460$).

Table 6. Strength and body composition results for full body and split body training protocols. Values are presented as mean ± SD.

	Full body training protocol			Split body training protocol		
Variables (units)	Pre-training	Post-training	% change	Pre-training	Post-training	% change
Bench press (kg)	102.6 ± 18.3	109.9 ± 18.8*	7.1	103.1 ± 18.3	109.6 ± 16.2*	6.3
Squats (kg)	128.6 ± 23.6	137.8 ± 22.7*	7.2	131.1 ± 19.6	138.4 ± 21.5*	5.6
BF (%)	18.5 ± 4.6	17.8 ± 4.7*	-3.8	17.9 ± 4.6	17.5 ± 4.3*	-2.2
BM (kg)	93.3 ± 10.9	93.2 ± 9.5	-0.1	93.4 ± 9.72	93.2 ± 9.3	-0.2
FM (kg)	17.6 ± 6.2	16.9 ± 5.8*	-4.1	17.0 ± 5.7	16.5 ± 5.3**	-2.5
FFM (kg)	75.7 ± 6.7	76.3 ± 5.9	0.8	76.4 ± 5.7	76.7 ± 5.6**	0.4

Key: BF % = body fat percentage; BM = body mass; FM = Fat mass; FFM = fat free mass; kg = kilogram units; * = $P < 0.01$; ** = $P < 0.05$

Table 7. Salivary hormonal results for full body and split-body training protocols. Values are presented as mean ± SD.

	Full body training protocol			Split body training protocol		
Variables (units)	Pre-training	Post-training	% change	Pre-training	Post-training	% change
Sal-T (pg/mL)	82.3 ± 38.6	89.5 ± 42.5	8.7	70.5 ± 26.7	84.7 ± 30.6*	20.1
Sal-C (µg/dL)	0.26 ± 0.25	0.23 ± 0.20	-11.5	0.18 ± 0.21	0.24 ± 0.19	33.3
Sal-T/C ratio (arbitary)	427.7 ± 288.5	536.0 ± 240.2	25.3	632.8 ± 468.7	487.0 ± 303.4**	-23.0

Key: Sal-T = salivary testosterone; Sal-C = salivary cortisol; Sal-T/C ratio = salivary testosterone / cortisol ratio; * = P < 0.01; ** = P < 0.05

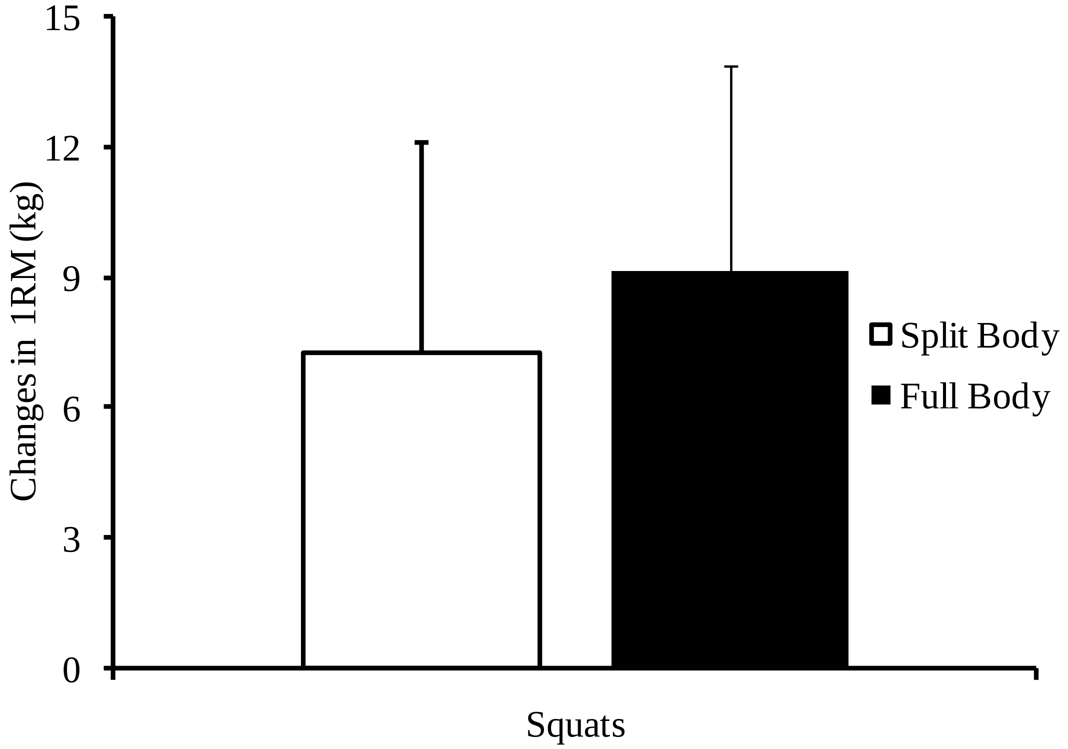

Figure 6: Changes in SQ 1RM strength after performing the FB and SB training protocols (mean ± SD).

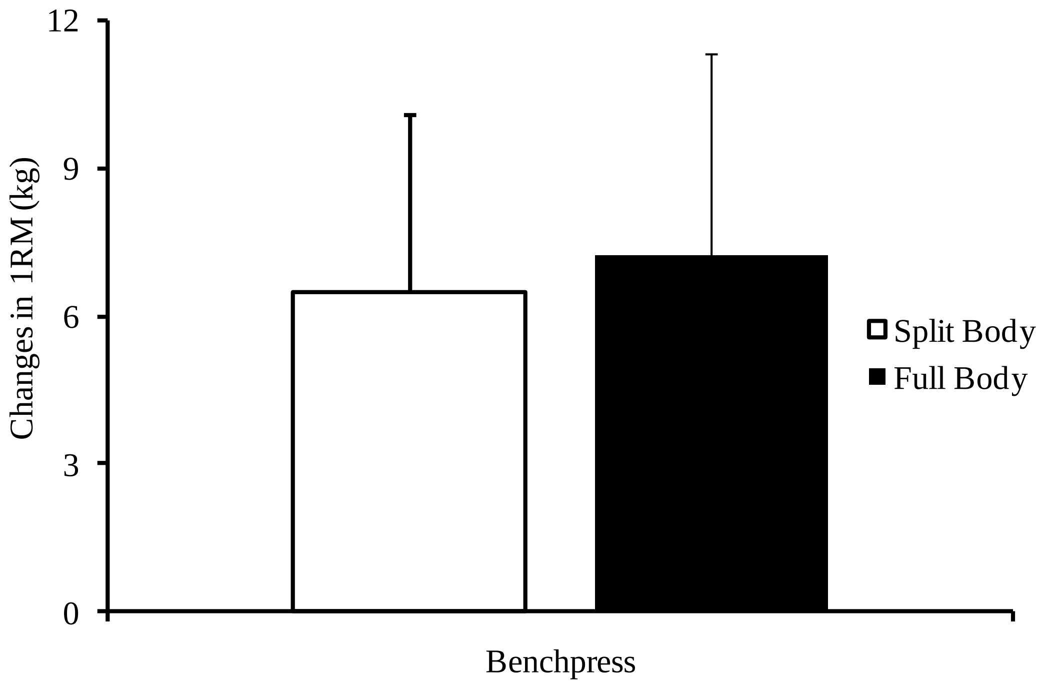

Figure 7: Changes in BP 1RM strength after performing the FB and SB training protocols (mean ± SD).

4.2.0 Body composition changes

4.2.1 Percent Body Fat (% BF)

Both the FB and SB protocols resulted in significant reductions in % BF (FB, p < 0.001; SB, p = 0.005). However, as seen in Figure 8, the magnitude of the decrease in % BF (FB, -3.8%; SB, -2.2%) were not statistically different between the two training protocols (p = 0.139).

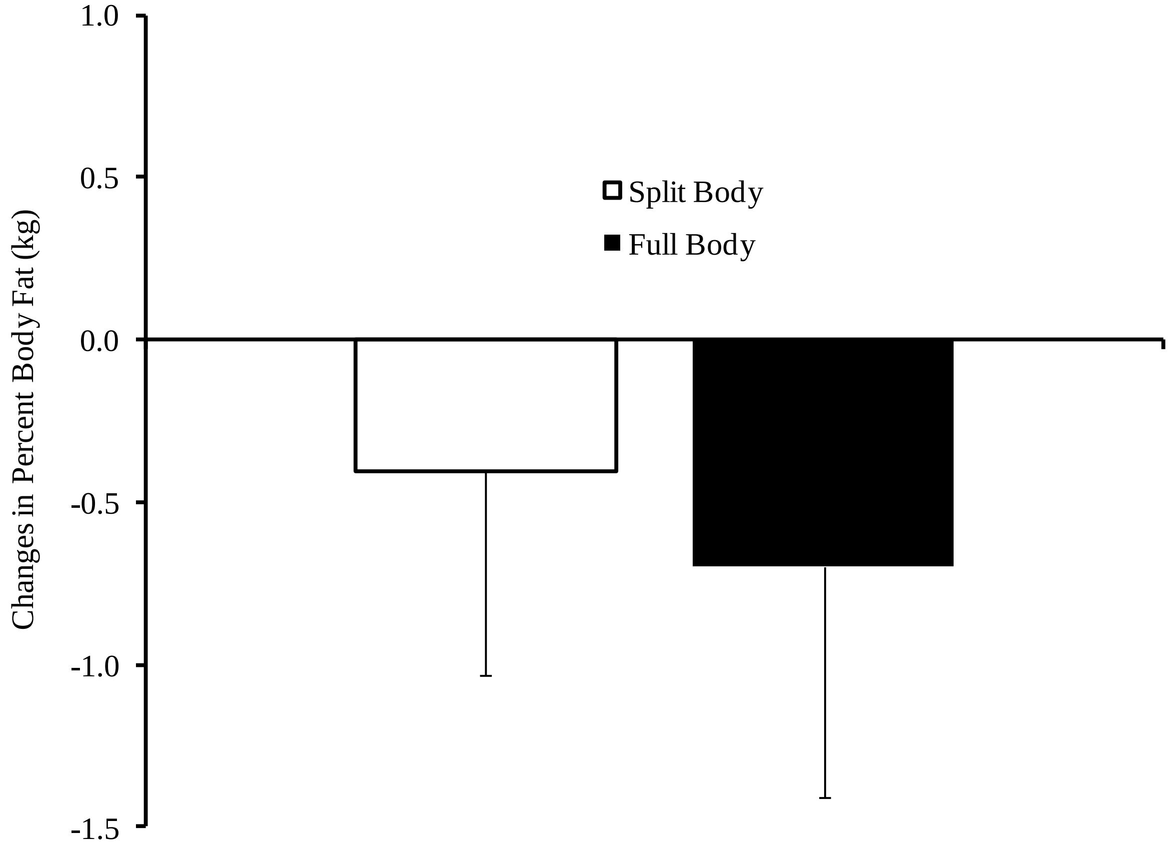

Figure 8: Changes in % BF after performing the FB and SB training protocols (mean ± SD).

4.2.2 Fat Mass (FM)

Both the FB and SB protocols resulted in significant reductions in FM (FB, p = 0.001; SB, p = 0.012). However, as seen in Figure 9, the magnitude of the decrease in FM (FB, -4.1%; SB, -2.5%) were not statistically different between the two training protocols (p = 0.144).

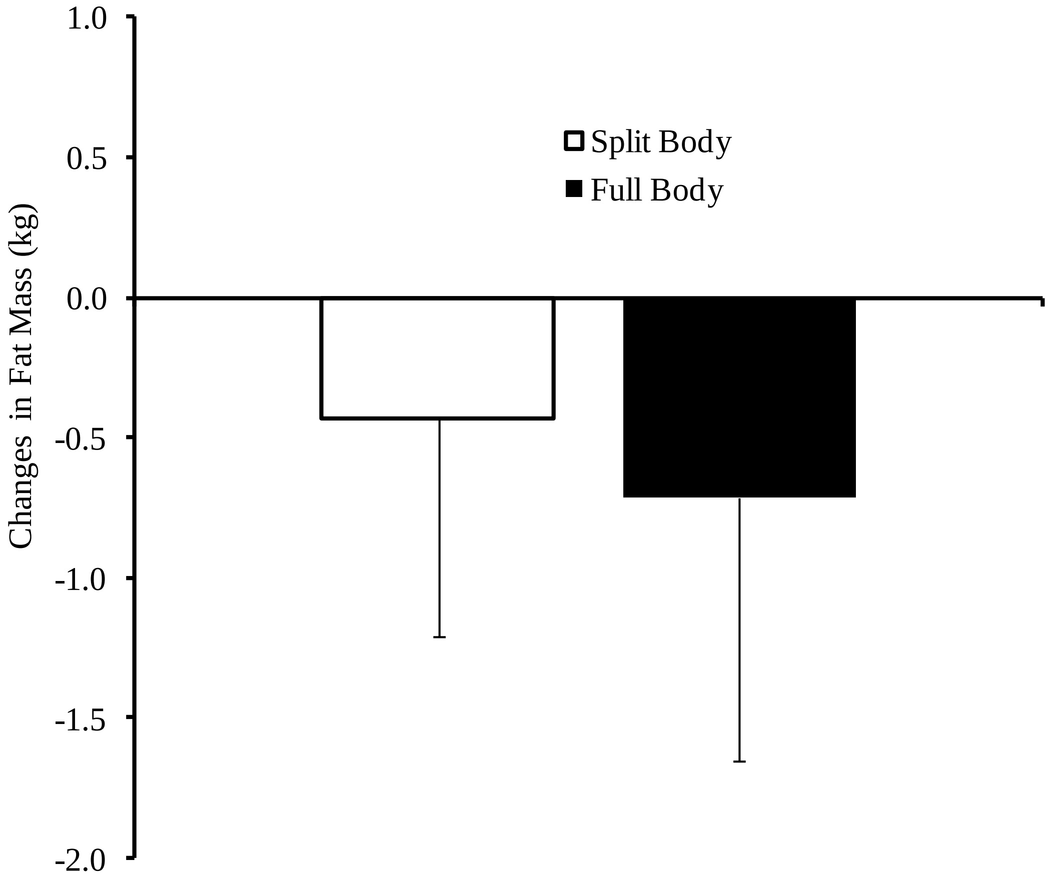

Figure 9: Changes in FM after performing the FB and SB training protocols (mean ± SD).

4.2.3 Fat Free Mass (FFM)

Both training protocols produced a small increase in FFM (Figure 10). This was significant for the SB protocol (p = 0.021) but not for the FB protocol (p = 0.080). The magnitude of the FFM changes (FB, 0.8%; SB, 0.4%) were not statistically different between the two training protocols (p = 0.406).

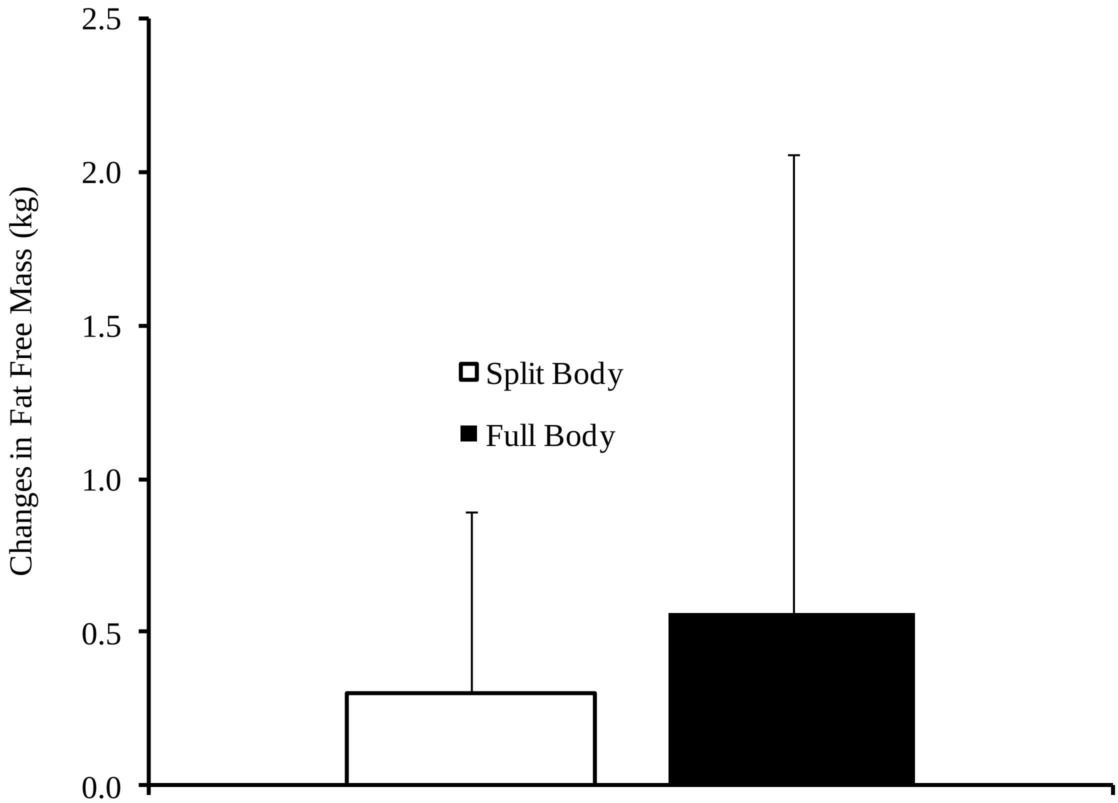

Figure 10: Changes in FFM after performing the FB and SB training protocols (mean ± SD).

4.3.0 Resting salivary hormone responses

4.3.1 Sal-T responses

There was a significant increase in the resting Sal-T responses following the SB protocol ($p = 0.005$) while there were no changes after the FB protocol ($p = 0.498$) (see Figure 11). The magnitude of the Sal-T responses (SB, 20.1%; FB, 8.7%) were not statistically significant between the two protocols ($p = 0.513$).

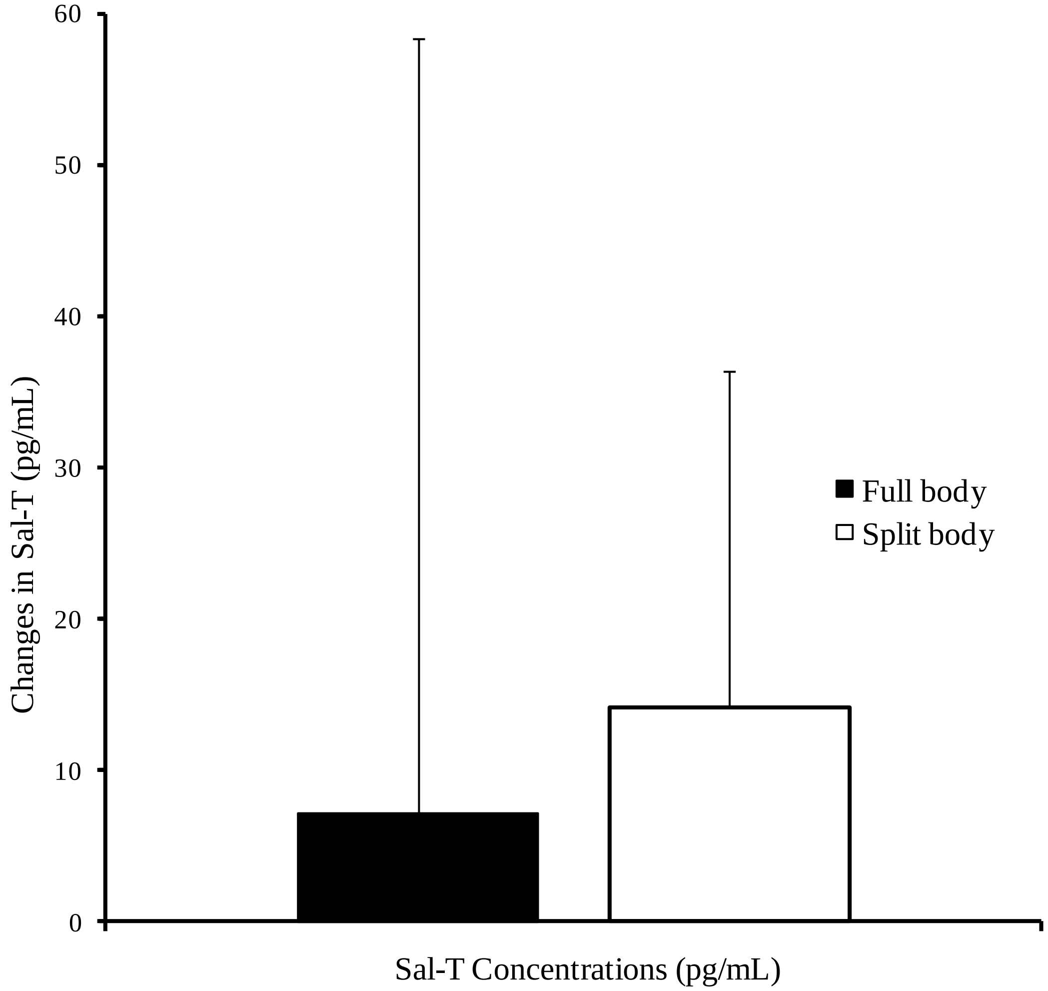

Figure 11: Changes in Sal-T concentrations after performing the FB and SB training protocols (mean ± SD).

4.3.2 Sal-C responses

The FB and SB protocols did not induce any significant changes in resting Sal-C (FB, p = 0.585; SB, p = 0.123) (see Figure 12). Furthermore, the magnitude of the Sal-C responses (FB, -11.5%; SB, 33.3%) were not statistically different between the two training protocols (p = 0.062).

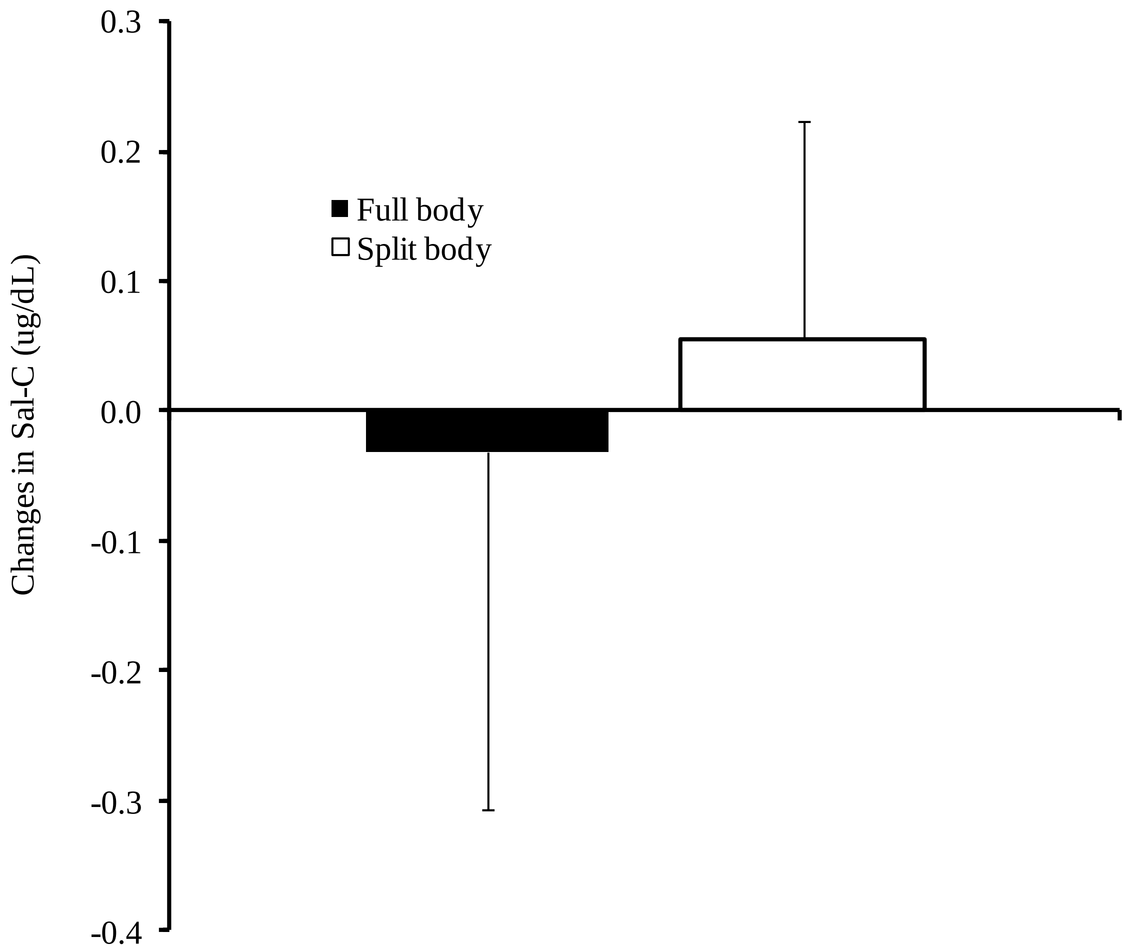

Figure 12: Changes in Sal-C concentrations after performing the FB and SB training protocols (mean ± SD).

4.3.3 Sal-T/C Ratio

Both the FB and SB protocols did not produce any changes in the Sal-T/C ratio (FB, p = 0.073; SB, p = 0.166) (see Figure 13). However, between-group analyses indicated that the magnitude of the increase in the Sal-T/C ratio (p = 0.037) was greater for the FB (25.3%) than the SB (-23.0%) group.

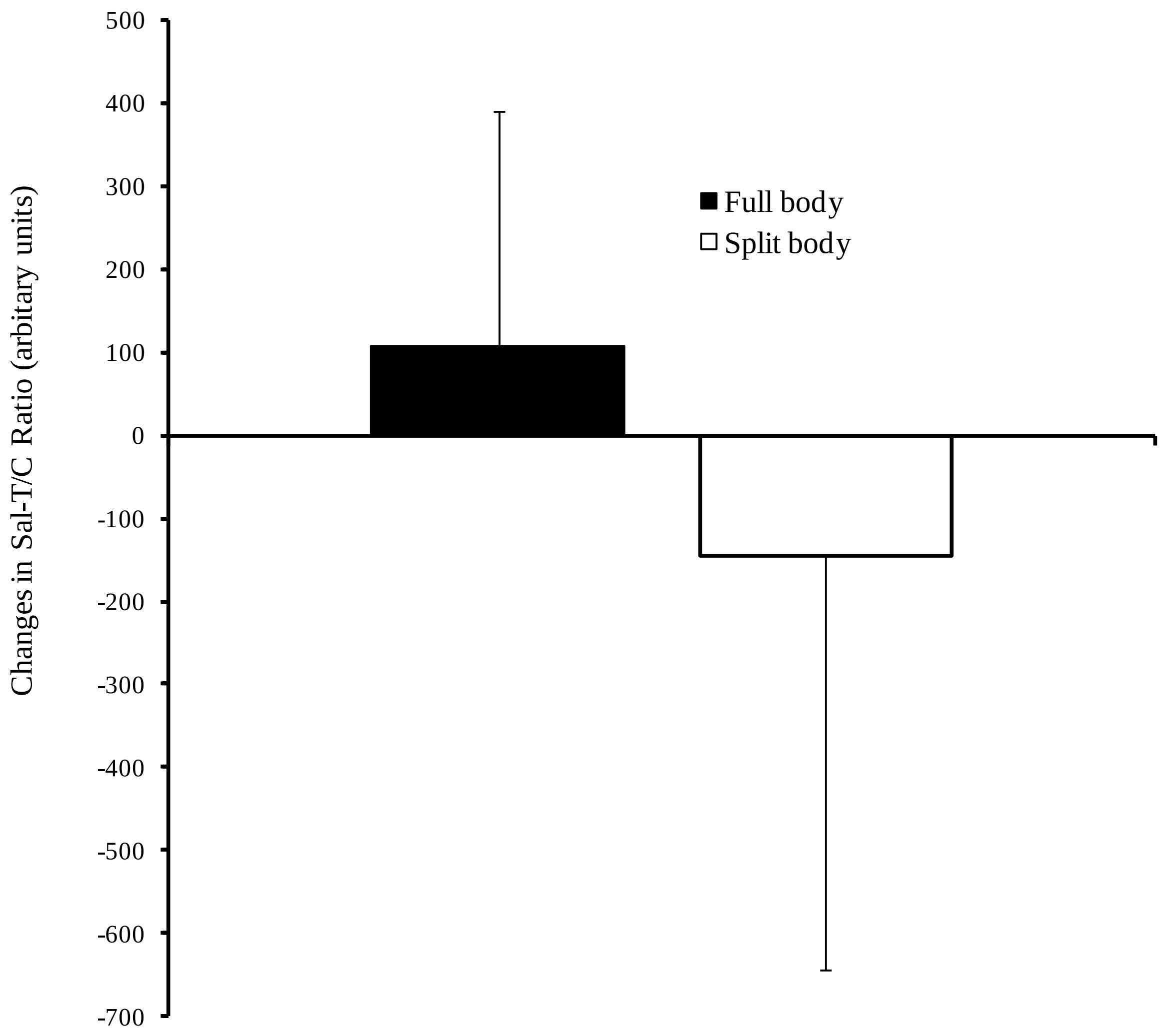

Figure 13: Changes in the Sal-T/C ratio after performing the FB and SB training protocols (mean ± SD).

5.0 CHAPTER FIVE - DISCUSSION

The purpose of this study was to examine and compare the effects of two equi-volume training protocols (FB and SB) upon strength, body composition and salivary hormones (Sal-T and Sal-C) in strength-trained males. There were a number of significant within-group changes that occurred during the training period. In particular, the FB and SB protocols both showed significant increases in strength and reductions in fat mass and percent body fat. The resting hormonal responses were less consistent with significant improvements in the resting Sal-T responses observed during the SB protocol only, while there were no significant within or between group changes in the resting Sal-C responses to the training protocols. A between-group difference was observed for the Sal-T/C ratio with an improvement of 25.3% after FB compared to a decrease of 23% after the SB protocol.

5.1 Strength changes

In support of our initial hypothesis, significant within-group strength differences were observed for both training protocols (FB and SB). The FB improved by 9.1kg in squat (SQ) and 7.3kg in bench press (BP) while the SB improved by 7.3kg in SQ and 6.5kg in the BP respectively. There were no significant between group strength differences.

Two similar equi-volume studies (Candow & Burke, 2007; McLester et al., 2000) attempted to examine the effects of training frequency on performance and endocrine adaptations. Candow and Burke (2007) performed an equi-volume study using untrained male and female participants over a six week training period. Participants were put into two groups: group one performed two workouts per week (3 sets per exercise) while group two performed three workouts per week (2 sets per exercise). The authors noted similar strength improvements in both groups for the squats (27% v 27%) and bench press (22% v 30%). Although Candow and Burke (2007) utilised an untrained population, their results supported the current findings in that both study groups produced similar increases in strength when performing short-term equi-volume resistance training.

McLester et al. (2000) used an equi-volume protocol to investigate whether performing one day per week (low frequency) resistance training was as effective as three days per week resistance training using strength-trained athletes over a twelve week period. Both groups improved their strength performance, but the high frequency group had greater improvements compared with the low frequency group in the bench press (27% v 10%), leg press (46% v 22%) and leg curl (47% v 25%) exercises. The authors concluded that spreading the total training frequency from one to three days per week produced superior training adaptations.

Although both protocols in our study had the same weekly volume they did differ in terms of the training frequency for different muscle groups and recovery periods between sessions. For instance, the FB protocol required subjects to perform exercises for all seven muscle groups evenly over each of the three training sessions per week. Conversely, the SB protocol required subjects to perform all exercises for specific muscle groups in one training session per week. Therefore, the subjects performing the FB had a 48 hour recovery period between consecutive training sessions compared to the SB group which had at least five days rest and recovery between same muscle training sessions. The similar strength improvements observed in this study could have been the result of a shorter training period of only four weeks, as opposed to the 12 week training period used by McLester et al.(2000).

A recently published article by Argus et al. (2010) supports the importance of training volume as a moderator of strength adaptations. Following a 6-week detraining / reduced volume phase, the authors investigated the effects of a high volume pre-season training protocol on strength, power, body composition and fatigue in professional rugby union players. All participants performed at least 5 resistance exercise sessions each week, concurrently with aerobic and anaerobic conditioning sessions depending on the goal of each training session. They had moderate strength improvements of 13.6 kg for bench press and 17.6 kg for the box squats after the training period. The improvements observed by Argus et al. (2010) were substantially more than those in our study, suggesting that the strength gains reported during this study were a result of the high training volume and how it was distributed across the training week. Additionally, the manipulation of training intensity may have also contributed to the greater strength improvements found in this study.

Our strength changes were comparable with previous literature (Kraemer, Stone, O'Bryant, & Conley, 1997; Paulsen, Myklestad, & Raastad, 2003) which has used strength-trained subjects to examine the physiological effects of resistance training over longer training periods. For example, two studies (J. B. Kraemer et al., 1997; Paulsen et al., 2003) investigated the strength improvement of the SQ exercise. The SQ strength improved by 17.5% after 6 weeks (Paulsen et al., 2003) and 19% after 14 weeks (J. B. Kraemer et al., 1997) compared to the 8% improvement after four weeks in this study. Another group of researchers investigated the strength improvements of the BP exercise. BP strength improved by 22% after 9 weeks (Buford et al., 2007), 18.5% after 12 weeks (McLester et al., 2000) and 11% after 12 weeks (Monteiro et al., 2009) compared to the 6.5% improvement from the current training study. It appears that strength-trained populations can achieve reasonable changes in strength through resistance training of varying durations. Nonetheless, these changes do not appear to be linear and are dependent on many training variables including the training volume, recovery periods between exercises, sets and sessions.

Closer inspection of our results indicates that the improvements in lower body (SQ) strength (FB, 9.1 kg; SB, 7.3 kg) and upper body (BP) strength (FB, 7.3 kg; SB, 6.5 kg) were similar between muscle groups. However, the lower body improvements did appear superior to upper body improvements and so our study findings were in agreement with other studies that have reported superior strength improvement in the lower body muscles compared to upper body muscles (Buford et al., 2007; Campos et al., 2002; McLester et al., 2000; Monteiro et al., 2009; Paulsen et al., 2003; M. R. Rhea et al., 2002). Paulsen et al. (2003) proposed that the large differences in the strength response between lower and upper body muscles may be related to their relative involvement during daily tasks. For example, the quadriceps and hamstring muscles (lower body muscles) were antigravity and propulsive muscles, respectively, and were exposed to a greater total load per day, as a result of carrying the body mass. In contrast, the pectoral or biceps (upper body muscles) were not generally exposed to the same amount of work during daily activities. Consequently, the lower body may require a higher training volume per session to produce greater strength improvements compared with the upper body.

Our strength results suggested that FB and SB training protocols both produce similar significant increases in lower and upper strength after 4 weeks of training in experienced trainers. However, if our results were extrapolated over a longer training period (e.g. over 8, 16 or 24 weeks) as is particularly common among researchers and in the training of athletes (Campos et al., 2002; J. B. Kraemer et al., 1997; Monteiro et al., 2009), any possible between-group differences may have become more noticeable and of some practical significance.

5.2 Body composition changes

Significant body composition changes were observed for the FB and SB training protocols. The FB decreased by 4.1% in fat mass (FM), 3.8% in percent body fat (% BF) and 0.8% in fat free mass (FFM). The SB decreased by 2.5% in FM, 2.2% in % BF and 0.4% in FFM. There were no significant between-group differences in body composition. Previous equi-volume studies have examined the effects of different resistance training protocols on body composition. For example, two equi-volume studies (Candow & Burke, 2007; McLester et al., 2000) showed trends towards improvements in FFM of between 1.4 to 8% after 6 and 12 weeks respectively. There were also trends towards decreases in BF of 4-7% after 9 weeks (Buford et al., 2007) and 6-8% after 12 weeks (McLester et al., 2000). These findings suggest that small to moderate increases in FFM can occur in conjunction with a reduction in % BF during moderate to long term training durations (Buford et al., 2007; McLester et al., 2000).

Our findings indicated that there were significant increases in FM and decreases in % BF; however there was a lack of improvements in FFM across the (FB) 0.8% and (SB) 0.4% training protocols. Several factors may explain the lack of change in FFM including the short training duration, the absolute volume and intensity of training, as well as nutritional factors. Previous researchers (Candow & Burke, 2007; McLester et al., 2000) did report improvements in FFM (1-8%) after 12 weeks of resistance training and so it may be possible that, had the training period been longer, for example, 8 or 12 weeks then significant improvements in FFM may have occured.

A study by Baker et al. (1994) has suggested that an increase in lean body mass was the main reason for strength gains in weight trained individuals. Our findings partially supported this study as both our training protocols appeared to reduce % BF and FM while also showing significant improvements in SQ and BP strength. However there was a lack of changes in FFM within our protocols. It must be remembered, that the lack of FFM changes were observed in a strength-trained male population with over two year's resistance training experience. And thus, any body composition improvements in this study population are difficult to accomplish, especially during a short training duration of only four weeks.

A recent article by Argus et al. (2010) reported improvements in body composition in conjunction with improvements in strength following a similar four week training period. This training study highlighted the importance of weekly training volume, for example all subjects in this study performed at least five high volume training sessions per week. In contrast, our study population only performed three training sessions per week. Argus et al. (2010) found significant improvements in FFM (2.2 kg), flexed upper arm girth (0.6 cm) and mid thigh girth (1.9 cm), while there was also a decrease in the sum of eight skin-folds (-11.0 mm). These findings suggested that protocols with a high training volume, high training frequency (up to 5 or 6 sessions per week) and with a moderate intensity significantly improved body composition training variables. While there were no between-group differences for our body composition variables, extrapolation of our findings over a longer training period (e.g. over 8, 16 or 24 weeks) as is particularly common among researchers and in the training of athletes (Buford et al., 2007; Candow & Burke, 2007; McLester et al., 2000) the between-group differences may have been of considerable practical significance.

5.3 Resting Sal-T concentration changes

The SB protocol resulted in a significant (20%) increase in Sal-T whereas there were no significant changes seen across the FB protocol. In addition, there were no differences between the two groups. The effects of resistance training on the resting concentrations of T have been studied extensively by previous researchers, with much equivalence in results. A previous training study by Ahtiainen et al. (2003) reported relationships between resting T concentrations and improvements in strength performance. In particular, they found that improvements in maximal force (1 RM lifts) in strength athletes were highly correlated with improvements in the resting T concentrations (r = 0.84) after the 21 week training period. The rationale for measuring resting T concentrations was to emphasise its importance to strength development in trained and untrained athletes.

Many studies have not shown any significant changes in the resting T concentrations (W J Kraemer et al., 1999; W. J. Kraemer et al., 1998; McCall et al., 1999). In contrast, other studies have shown that adjustments in training volume and training intensity can modify changes in the resting T concentrations for strength-trained athletes (Ahtiainen, Pakarinen, Alen et al., 2003; Fry et al., 1994; Häkkinen et al., 1987; Izquierdo et al., 2006). Ahtiainen et al. (2003) reported increases in resting T concentrations for strength trained athletes (SA) during the first 14 weeks of a 21 week training study, with this associated with an increase in the training volume. However, the remaining training period (7 weeks) saw a decrease in the training volume and a subsequent reduction in the resting T concentrations. These results were similar to those of Hakkinen et al. (1987) who found that the T concentrations increased and decreased relative to changes in training volume.

Another training study by Izquierdo et al. (2006) examined and compared the effectiveness of high intensity (training to failure) with moderate intensity (non-failure) resistance training over an 11-week period. They suggested that performing an acute high intensity training bout resulted in significantly decreased T concentrations. If such an effect was to happen over multiple high intensity sessions, it might result in a chronic reduction in the resting T responses. These findings tell us that high volume training protocols improve resting T responses while repeated high intensity training protocols potentially impede or decrease resting T responses.

Our findings indicated that that there were significant changes in the resting Sal-T concentrations for the SB (20%) but not the FB (8.7%) protocol. Both protocols had the same weekly training volume (equi-volume), but differed through variations in the training frequency over the training week. For example, the FB utilised a moderate intensity (8 RM), low volume (i.e. 2-3 sets per exercise) and high frequency (i.e. 3 sessions per week) regime where all the muscle groups were stimulated equally during three identical training sessions each week. Conversely, the SB utilised a moderate intensity (8 RM), high volume (i.e. 6-9 sets per exercise) and low frequency (i.e. 1 session per muscle group per week) regime which stimulated individual muscle groups during three different weekly training sessions. The significant improvement observed in the SB protocol (20%) may therefore have been the result of the high training volume (6-9 sets per exercise) used compared to the low volume used during the FB protocol.

Several factors may explain the lack of change in Sal-T concentrations for the FB protocol such as differences in our baseline resting concentrations (i.e. FB protocol 17% higher than the SB protocol). Consequently, our subjects would have likely had less potential for further increases in their Sal-T concentrations as a result of FB training. The differences observed could also be attributed to individual responses to training, since the endocrine response to 'stressors' (e.g. exercise) are inherently variable (Beaven et al., 2008).

5.4 Sal-C concentration changes

There were no significant within or between group differences observed for Sal-C concentrations after both training protocols. As a stress hormone, C is often used to represent different levels of training strain (M.C. Uchida et al., 2009). Previous research has reported that changes in training volume and intensity can modify C concentrations (Crewther et al., 2008; Hakkinen & Pakarinen, 1993; Smilios et al., 2003; Zafeirdis, Smilios, & Considine, 2003). Overall, the greater the training strain imposed by various training protocols on the neuromuscular system, the greater the changes in resting C concentrations (M.C. Uchida et al., 2009). Our results indicated that there were no significant within or between group changes in the Sal-C concentrations for both training protocols and that several factors may explain the lack of resting Sal-C concentrations.

Our lack of change in Sal-C may partially reflect a lack of absolute training volume in both training protocols, given that a higher training volume is needed to produce sufficient strain on the neuromuscular system and therefore stimulate long-term changes in C secretion (M.C. Uchida et al., 2009). Hakkinen et al. (1987) reported a significant increase in the C concentrations following a highly stressful (high volume and intensity) short duration study. In addition, the same authors found that when the training volume had been reduced, the resting C concentrations also reduced. The number of training sessions performed each week potentially contributed to the lack of Sal-C responses. Our two protocols were only required to perform three training sessions per week for four weeks, when a higher frequency (4-5) of training sessions per week such as that performed in the study by Argus et al. (2010) may have increased the resting Sal-C concentrations.

Differences in our baseline Sal-C concentrations could have contributed to the lack of significant resting Sal-C changes. For example, closer inspection of the baseline Sal-C concentrations for both protocols revealed that the FB protocol was substantially (44%) higher than the corresponding SB protocol. Another possible reason for our finding could be related to the metabolic effects of C. During the post-exercise recovery period, C contributed to maintain sufficient rates of glycogen synthesis, protein turnover and supply of protein synthesis by amino acids (A. Viru, 1996). Thus, the SB protocol may have depleted the ATP-PC glycogen stores in the exercising muscle more quickly than did the FB, and as a consequence required greater C secretion to stimulate release of glucose into the blood. However, this was very unlikely in this study as the saliva samples were taken at least three days after the final training session, that is, the last session was Friday of week 4 and 16, while the sample was taken on the Monday of the following week. Other factors that may have affected our Sal-C concentrations included psychological modulators such as stress from the training sessions and/or other external influences.

5.5 Sal-T/C Ratio changes

There were no significant within group differences observed for both training protocols. However there were significant between group differences observed for the Sal-T/C ratio, with an increase in the ratio for the FB protocol (25%) significantly greater than the decrease (-23%) for the SB protocol. The significant between-group difference in Sal-T/C ratio in our study appeared to have resulted from a small and non-significant increase in Sal-T as well as a small and non-significant decrease in Sal-C concentrations for the FB protocol. Furthermore, our results appeared to be of greater significance in short-term studies compared to long-term as significant differences would be more difficult to find during an extended (long-term) training period.

A short duration study by Gorostiaga et al. (1999) reported that improvements in strength occurred in conjunction with improvements in the T/C ratio. Gorostiaga et al. (1999) performed a six week study examining the effects of heavy resistance training on the T/C ratio in male athletes. They found that a significant increase in the T/C ratio was accompanied by considerable gains in the leg (13%) and arm (23%) strength. Their results were similar to the current study results in that, a significant improvement in the Sal-T/C ratio (20%) during the FB training protocol occurred in conjunction with improvements in the BP (7%) and SQ (7%) exercises. However, the other (SB) training protocol had similar strength and body composition improvements but showed a decrease in the Sal-T/C ratio (-23%). Another interesting observation from the current study was that the SB protocol showed a significant improvement in Sal-T responses (20%) compared to the FB protocol however it still did not manage to show any improvements in the ratio.

Several factors may explain the lack of significant changes in the Sal-T/C ratio including differences in our baseline Sal-T and Sal-C concentrations, lack of absolute training volume, frequency and intensity. On closer inspection of the Sal-T/C ratio there appeared to be a high variability in the hormonal concentrations (baseline levels). The variability in these concentrations may potentially make it hard for changes observed after weeks of training to be statistically significant.

Previous long term training studies also reported that improvements in the Sal-T/C ratio occurred in conjunction with improvements in performance (i.e. strength and body composition) for strength athletes (Ahtiainen, Pakarinen, Alen et al., 2003; Alen et al., 1988; Häkkinen, Pakarinen, Alén, & Komi, 1985). This was highlighted by Ahtiainen et al. (2003) who reported that improvements in maximal force (i.e. 1RM strength) for strength athletes after a 21 week training period were positively correlated with an increase in the post study T/C ratio ($r = 0.88$).

Kraemer et al. (1988) used the T/C ratio as an indicator of changes in the body's anabolic-androgenic activity, for example, an increase in T and/or a decrease in C was indicative of a potential state of anabolism. During the tissue remodelling process, catabolic hormones such as C contributed to the degradation of muscle protein during resistance training (see review by W.J. Kraemer & Ratamess, 2005). C also stimulated lipolysis in adipose cells and decreased protein synthesis in muscle cells resulting in greater releases of lipids and amino acids into circulation. During the recovery period, anabolic hormones such as T were thought to contribute to the remodelling of muscle protein by increasing protein synthesis and reducing protein degradation. This process eventually led to growth and repair of the muscles (see reviews by Crewther et al., 2006; W.J. Kraemer, 1992). Moreover, T may indirectly contribute to protein accretion by stimulating the release of other anabolic hormones, such as growth hormone (Crewther et al., 2006).

6.0 CHAPTER SIX - SUMMARY

Summary

Equi-volume training protocols are becoming increasingly used by researchers to examine and compare the effectiveness of different resistance training protocols. Keeping the training volume constant while manipulating other training variables allows researchers to focus on whether these variables (e.g. training frequency or training intensity) influenced the strength and conditioning adaptations. However, this was the first study to examine the training adaptations associated with two commonly used protocols (FB and SB) and to do this using a strength-trained population.

The findings in this experimental study demonstrated that two different training protocols can produce similar changes in strength and body composition in strength-trained males when equated by volume, which is consistent with some but not all research. Both FB and SB increased upper and lower body strength in the study population however, as indicated by other research, longer-term studies may be needed to reveal the magnitude of any differences between training protocols. It also appears that training using three or more training sessions per week (high weekly frequency) may provide a greater stimulus for muscle hypertrophy and strength improvement than performing one or two training sessions (low weekly frequency) per week.

The findings indicated that the body composition changes included decreases in FM and % BF, but not FFM. Previous researchers have shown improvements in FFM of between 1 - 8% after 12 weeks of resistance training, so it may be possible that longer training periods are needed for changes in FFM to occur. Overall, research suggests that training protocols that use high weekly volume, high training frequency (up to 5 or

6 sessions per week) and a moderate training intensity can produce positive improvements in body composition.

Despite the similar changes in muscle strength and body composition, we noted differences in the Sal-T responses to each training protocol. The SB protocol had elevated Sal-T concentrations compared to the FB protocol, but this did not appear to influence the other training adaptations that occurred. Studies on strength athletes have shown that high volume and/or high intensity training protocols can modify hormones and thus, impact on the performance adaptations. Perhaps the importance of changes in endogenous T and C is dependent on the absolute volume and/or intensity of training performed. Furthermore, the concomitant changes in hormones and performance may be subject-dependant, as indicated by correlational studies. Overall, this experimental study has further emphasised the importance of weekly training volume for improving training adaptations and influencing the hormonal environment. The use of the two commonly used protocols (FB and SB) appears to be effective at improving strength and body composition. Differences in the resting hormonal data primarily appear to be the result of differences in baseline levels.

Practical Applications

Based upon the findings of the current study and literature in this area, there are potentially many opportunities to enhance resistance training practice and research:

1. For strength trained athletes, prescribing a high weekly volume training protocol and using appropriate recovery periods may enhance training adaptations.
2. The results could be applied to other populations (e.g. elderly, injured) to promote strength and conditioning, injury rehabilitation and other health-related gains.
3. Strength and conditioning coaches, personal trainers, high performance coaches and health professionals are able to prescribe FB and SB resistance training protocols based on high weekly training volume more effectively and efficiently.
4. Strength-trained athletes benefit through improvements in strength and body composition in the short dedicated training windows (e.g. four weeks) that often limit training adaptations in professional athletes during their in-season.
5. Monitoring the hormonal responses (T and C) to different training protocols (FB and SB) will further develop our knowledge base and understanding of the underlying mechanisms for adaptation.

Limitations

The authors acknowledge the following limitations and delimitation of the current research study:

1. The subject inclusion criteria meant that the study findings may possibly only be applied to strength-trained males with at least two years resistance training experience.
2. The body composition assessments were carried out using 'manual' measurements (e.g. body fat callipers) that are subject to human error. An alternative assessment tool such as dual energy x-ray absorptiometry (DXA) or bio-impedance analyses (BIA) may have been more reliable & hence allow smaller changes to be detected.
3. Resting hormonal responses can be affected by many factors and show marked variability between testing occasions.
4. The chest and legs were subjected to a maximum of 9 sets of 8 repetitions (using 3 exercises) per week, while the smaller muscle groups were subjected to 6 sets of 8 repetitions per week (using 1 or 2 exercises). It could be argued that this training volume was not sufficient for this study population.
5. The washout period of 8 weeks may have been too long. Subjects may have continued performing more resistance exercise or other training within this period without the knowledge of the investigators. Potentially influencing the training adaptations (strength, body composition and hormonal concentrations) associated with the current training study.
6. The training periods for FB & SB protocols were of limited duration, so different adaptations may have occurred over longer training period (such as 8 or 12 weeks).
7. We did not monitor a non-training control group across the duration of the experimental study.

Recommendations

There are a number of areas that require further examination both in research and practice. Future research should address the possible effects of longer training periods using the same training protocols examined in this study. This analysis would provide a better understanding of the underlying stimulus for subsequent training adaptations. Performing a training protocol using three or more training sessions per week (high weekly training volume) may provide a greater stimulus for muscle hypertrophy and strength improvement than performing one or two training sessions (low volume) per week. Changes in hormonal responses, particularly T and C and the resultant Sal-T/C ratio have been implicated in or used as markers of over-reaching/overtraining. Therefore further research into the use of these hormones as markers of overreaching/overtraining is recommended to establish a greater understanding of the hormonal process and its effects on training adaptations. Further investigation into the resting hormonal responses (especially T and C) to resistance training using a strength-trained population is recommended, as the current study appeared to show highly variable baseline concentrations for T and C. Consequently these findings made it very difficult to analyse the hormonal data, especially the Sal-T/C ratio.

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APPENDICES

Appendix 1: Participant Information Sheet

AUT UNIVERSITY

SPORTS PERFORMANCE RESEARCH INSTITUTE, NEW ZEALAND
AN INSTITUTE OF AUT UNIVERSITY

Date Information Sheet Produced:
22/05/2009

Project Title
The effect of two-equal volume resistance training protocols upon muscle strength and hormones in strength trained males

An Invitation
You are invited to take part in a study with the aim of identifying which resistance training protocol (full body or split body) will elicit greater training responses. Participation in this study is completely voluntary (your choice) and if you choose to accept this invitation you may withdraw at any time without any adverse consequences.

What is the purpose of this research?
The overall aim of this project is to examine differences in the strength and hormonal response to two resistance training protocols (full body & split body) that involve the same weekly training volume.

How was I chosen for this invitation?
You are male and are experienced in resistance training (> 3 times per week) for more than two years prior to this research and you have no current injuries or conditions that will affect your participation in this study.

What will happen in this research?
You will be split into two groups and assessed for body composition (proportion of body fat and muscle), muscle strength and hormones before, during and after a 16-week training period. The protocol will consist of two 4-week training periods separated by an 8-week washout (detraining) period, at which time you will be able to perform your regular training programme.

During the first 4-week training period, half of you will perform a full body (FB) and the other half a split-body (SB) training protocol. After the 8 week washout period, both groups will crossover and perform the other protocol for the second 4-week training period. Both groups will train 3 days per week and perform the same number of sets and repetitions each week; however, the FB group will exercise all major muscle groups on each of the three days. In contrast, the SB group will only exercise a sub-set of major muscle group on each training day. Rest periods will be the same with 2 minutes between sets and 3 minutes between exercises. You will also be asked to record your lifts for each session in a training diary.

You will be required to perform body composition and strength assessments pre-training (prior to week 1); at the end of training period 1 (week 4); at the start of training period 2 (week 13) then finally at the end of training period 2 (week 16). Salivary hormonal samples will also be collected from you during these periods. Figure 1 outlines when the assessments will be performed and salivary samples collected.

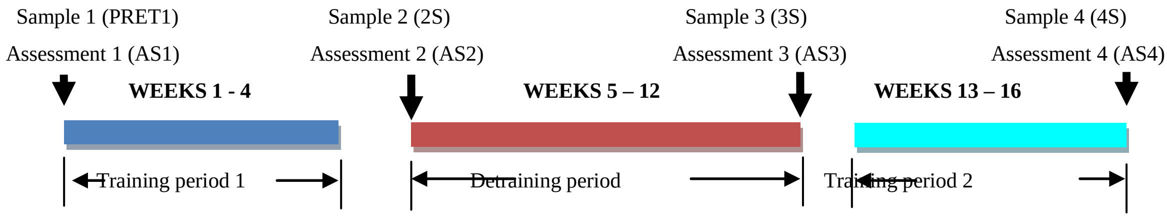

Figure 1: Sampling and assessment time-points during training study. Total weeks of training study = 16 weeks. PRET1 / AS1 = Pre training sample /assessment taken prior to the start of training period 1; 2S and AS2 = Sample and assessment 2 taken at the end of Training period 1; 3S and AS3 = Sample and assessment 3 taken at the start of Training period 2; 4S and AS4 = Sample and assessment 4 taken at the end of Training period 2.

Body composition assessment

Body composition refers to those basic components making up the human body. These include total body mass and the percentage of body fat, which will then be used to calculate fat-free mass. These measurements will be assessed by the leading researcher, qualified with the International Society for the Advancement of Kinanthropometry. A wall stadiometer will be used to determine stretch height to the nearest 0.1cm. Body mass will be measured to the nearest 25g using an electronic scale. You will need to be partially dressed during all assessments; therefore they will be performed in a private room. If you wish, you can have a support person present if you wish for these assessments.

Strength assessment

Upper (bench press) and lower extremity (parallel squat) strength will be measured by determining the maximum amount of weight that could be lifted for one repetition (1 RM) as described elsewhere by Hickson et al, (1988). These two assessments will be performed within the same session prior to week 1 then during weeks 4, 13 & 16 with 15 minutes rest separating each.

Hormone assessment

The saliva samples will be collected in 2-mL sterile containers (Labserve, NZ). The samples will be numbered and kept in a standard chilly bin at a secure lab (at HortResearch, Hamilton) at -20°C until assay. At the completion of the study, the remaining sample may be destroyed or returned to the participant.

What are the discomforts and risks?

The likelihood of any discomforts, risk or injuries occurring during training will be minimal, because strength-trained subjects will be recruited and a standard warm-up will be performed before each assessment and training session.

How will these discomforts and risks be alleviated?

The risks involved with exercise are minor and further reduced by a warm-up. Strength-trained subjects will be recruited to participate while trained exercise professionals will supervise all assessments and training sessions.

What are the benefits?

Full body and Split body resistance training: This project will contribute to our understanding of the potential differences in adaptation for split body or full body resistance training programmes. Examining the hormonal responses will provide insight regarding one of the potential mechanisms responsible for this possible difference in adaptation. Such information will allow conditioners and personal trainers to better match the form of training to the adaptations required by the clients.

The results will be made available to participants in a brief report, written in a non-technical manner. Results of this project will also be submitted for publication in an academic journal and for presentation at a conference. This data will also provide the basis for the students' Master's Thesis.

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 will my privacy be protected?

The data collected or published will not identify the participants in any way and will be kept confidential. All information collected will be stored in a locked or password secure file. At the end of the experiment, the unused samples will be destroyed or returned to the participant if requested. The results obtained will only be used for the purpose of this project.

What are the costs of participating in this research?

All testing will be conducted during and as a part of your regular training session. Therefore you will have to give no additional time to partake in this study.

What opportunity do I have to consider this invitation?

You will have one week (7 days) to accept this invitation. It is enforced that participation in this study is completely voluntary (your choice) and can withdraw at anytime (by contacting the researcher - see researcher contact details below) without any adverse consequences of any kind. If you require any further information feel free to contact the researcher (see researcher contact details below).

How do I agree to participate in this research?

You can agree to participate in this research by reading and signing the accompanying consent form. The researcher will be the primary point of contact for all participants throughout the whole process (recruitment, consent forms, data collection, etc).

Will I receive feedback on the results of this research?

The research results will be given to the participants to provide feedback on their progress, and to assist with the future prescription of their exercise programmes and training. Additionally participants can also be verbally provided their own data at the time of testing.

What are the roles of the police trainer and trainers in this research?
The police trainer, trainers and the researcher will use the work newsletter (electronic notice-board) to disseminate information regarding this research study. The trainer will help distribute posters for possible participants through electronic newsletters and on walls in the gymnasium. Furthermore, the trainer will also assist with administering exercises during training sessions. The trainer's assistance with this study is that of a research assistant and qualified trainer and is separate from any formal role he has in assessing the fitness of personnel.

What do I do if I have concerns about this research?
Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Justin Keogh, justin.keogh@aut.ac.nz, 09 921 9999 ext. 7617. Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, *madeline.banda@aut.ac.nz*, 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:
Taati Heke
Master of Science Candidate
Auckland University of Technology
Akoranga Drive, Northcote
Mobile: 0210 483 805
Email: taati.heke@fonterra.com

Project Supervisor Contact Details:
Dr Blair Crewther
Research Supervisor
Contact: 021 236 1410
Email: blair@optimalsports.co.nz

Project Supervisor Contact Details:
Dr Justin Keogh
Research Supervisor
Auckland University of Technology
Akoranga Drive, Northcote
Contact: +64 9 921 9999 ext. 7617
Email: justin.keogh@aut.ac.nz

Research Assistant Contact Details:
Shayne Harvey
Police trainer
Hamilton Central Police Station
Mobile: 021 630 241
Email: shayne.harvey@police.govt.nz

Approved by the Auckland University of Technology Ethics Committee on *22 July 2009*, AUTEC Reference number *09/125*

FULL BODY WORKOUT GROUP

- Both groups will train 3 days per week for 4 weeks.
- They will perform the same number of sets and repetitions each week
- **Rest periods:** 1 minute between sets; 1 minute between exercises.
- You will be required to record your lifts for each session in a training diary.
- You will be asked to perform all your reps / sets as close to your 8 RM as possible (100% effort for every session).
- Body composition, strength assessments, Saliva sample collection will also be performed at various stages of training programme (4 in total).

Full-body Workout				
Legs Squat 3 x 8 **Chest** Flat Bench Press 3 x 8 **Back** Bent Over Row 3 x 8 **Shoulder** DB Shoulder Press 2 x 8 **Biceps** DB Supination Curls 2 x 8 **Triceps** Close Grip BP 2 x 8 **Calves** Standing Calf Raise 2 x 8	Rest Day	**Legs** Squat 3 x 8 **Chest** Flat Bench Press 3 x 8 **Back** Bent Over Row 3 x 8 **Shoulder** DB Shoulder Press 2 x 8 **Biceps** DB Supination Curls 2 x 8 **Triceps** Close Grip BP 2 x 8 **Calves** Standing Calf Raise 2 x 8	Rest Day	**Legs** Squat 3 x 8 **Chest** Flat Bench Press 3 x 8 **Back** Bent Over Row 3 x 8 **Shoulder** DB Shoulder Press 2 x 8 **Biceps** DB Supination Curls 2 x 8 **Triceps** Close Grip BP 2 x 8 **Calves** Standing Calf Raise 2 x 8

SPLIT BODY WORKOUT GROUP

- Both groups will train 3 days per week for 4 weeks.
- They will perform the same number of sets and repetitions each week
- **Rest periods:** 1 minute between sets; 1 minute between exercises.
- You will be required to perform at least one warm-up set before starting each exercise.
- Perform core exercises in between or after workouts
- You will be required to record your lifts for each session in a training diary.
- You will be asked to perform all your reps / sets as close to your 8 RM as possible (100% effort for every session).
- Body composition, strength assessments, Saliva sample collection will also be performed at various stages of training programme (4 in total).

Split-body Workout				
Chest Flat bench press 3 x 8 Decline dumb-bell press 3 x 8 Incline dumb-bell press 3 x 8 **Shoulders** Dumb-bell shoulder press 6 x 8 **Biceps** Dumb-bell supination curls 6 x 8	**REST DAY**	**Legs** Squat 3 x 8 Leg curl 3x 8 Leg Press 3 x 8 **Calves** Standing Calf Raise 4 x 8 Seated Calf Raise 2 x 8	**REST DAY**	**Back** Bent over rows 3 x 8 Lat pull downs 3 x 8 Cable rows 3 x 8 **Triceps** Close-grip bench press 6 x 8

Appendix 2: Participant Consent Form

CONSENT FORM

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:

1. My participation in the project is entirely voluntary;
2. I am free to withdraw from the project at any time, without reason, and without any disadvantage;
3. I would like my samples destroyed within 12 months after analysis. ☐

   OR ☐

4. I would like my samples returned to me after analysis.
5. The collection of samples by methods previously described appears to be safe;
6. The results of the project may be published but my anonymity will be preserved.
7. I have agreed to my personal training results being obtained by the trainer at the end of this study.

   OR ☐

8. I have NOT agreed to my personal training results being obtained by the trainer at the end of this study.
9. I agree to take part in this project. ☐

.... ……..............

(Signature of participant) (Date)

Approved by the Auckland University of Technology Ethics Committee on *22 July 2009*, AUTEC Reference number *09/125*

Note: The Participant should retain a copy of this form

Appendix 3: Ethics Approval Sheet

M E M O R A N D U M

Auckland University of Technology Ethics Committee (AUTEC)

To: Justin Keogh

From: **Madeline Banda** Executive Secretary, AUTEC

Date: 26 June 2009

Subject: Ethics Application Number 09/125 **The effect of two-equal volume resistance training protocols upon muscle strength and hormones in strength trained males.**

Dear Justin

I am pleased to advise that the Auckland University of Technology Ethics Committee (AUTEC) approved your ethics application at their meeting on 15 June 2009, subject to the following conditions:

1. Clarification of the role of the Hamilton Police Department and the Police Trainer in relation to this study, and particularly:

   a. Clarification of why they are being provided with the results. Information about this is to be included in the Information Sheet;

   b. Clarification of and justification for the involvement of the Hamilton police staff support group rather than AUT Counselling in cases when counselling may be required;

2. Provision of a revised response to section D.4 of the application providing a more detailed recruitment protocol, including:

   a. Identification of which notice boards are being used;

   b. Clarification of how the email addresses are being obtained;

3. Provision of the email invitation that will be used;

4. Clarification of the storage arrangements for the saliva samples;

5. Inclusion of the AUT logo in the advertisement;

6. Revision of the Information Sheet as follows:

   a. Provision of more information about what is involved in the research;

   b. Definition of what is meant by the term 'body composition';

   c. Use of the required wording for the section titled 'What compensation…' as given in the Information Sheet exemplar in the Ethics Knowledge Base (accessible online via http://www.aut.ac.nz/research/research-ethics) if this section is needed.

I request that you provide the Ethics Coordinator with a written response to the points raised in these conditions at your earliest convenience, indicating either how you have satisfied these points or proposing an alternative approach. AUTEC also requires written evidence of any altered documents, such as Information Sheets, surveys etc. Once this response and its supporting written evidence has been received and confirmed as satisfying the Committee's points, you will be notified of the full approval of your ethics application.

When approval has been given subject to conditions, full approval is not effective until *all* the concerns expressed in the conditions have been met to the satisfaction of the Committee. Data collection may not commence until full approval has been confirmed. Should these conditions not be satisfactorily met within six months, your application may be closed and you will need to submit a new application should you wish to continue with this research project.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at charles.grinter@aut.ac.nz or by telephone on 921 9999 at extension 8860.

Yours sincerely

Madeline Banda
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Owen Lance Taati Heke taati.heke@fonterra.com

Appendix 4: Participant Poster