THE MODERN NATURAL BODYBUILDER: DIETARY INTAKE, SUPPLEMENT USAGE, TRAINING DEMANDS, AND THEIR HEALTH IMPLICATIONS

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STATEMENT OF ORIGINALITY

I, Lachlan Mitchell, hereby declare that this thesis is my own work and does not, to the best of my knowledge, contain material from any other source unless due acknowledgement is made. This thesis was completed under the guidelines set out by The University of Sydney, and has not been submitted to any other university or institution as a part or a whole requirement for any higher degree.

For works that are either published, in press or currently under review and contain multiple authors, I declare that I was the principal researcher of all the manuscripts included in this thesis.

Name ______Lachlan Mitchell___

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LIST OF ABBREVIATIONS

AAS	Anabolic-androgenic steroids
AgRP	Agouti-related protein
BB	Bodybuilder
BIA	Bioelectrical impedance analysis
BIG	Bodybuilder Image Grid
BIG-O	Bodybuilder Image Grid - Original
BMI	Body mass index
CART	Cocaine- and amphetamine-regulated transcript
CI	Confidence interval
CRH	Corticotropin releasing hormone
DXA	Dual-energy x-ray absorptiometry
EAT-26	Eating Attitudes Test 26 items
ECF	Extracellular fluid
ED	Eating disorder
ES	Effect size
ICF	Intracellular fluid
MASS	Muscle Appearance Satisfaction Scale
MD	Muscle dysmorphia
MDI	Muscle Dysmorphia Inventory

MDDI	Muscle Dysmorphic Disorder Inventory
MDSQ	Muscle Dysmorphia Symptom Questionnaire
NBBRT	Non-bodybuilder resistance trainer
NEAT	Non-exercise activity thermogenesis
NPY	Neuropeptide y
POMC	Proopiomelanocortin
RMR	Resting metabolic rate
SD	Standard deviation
SNS	Sympathetic nervous system
T3	Triiodothyronine
TBW	Total body water

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ABSTRACT

Bodybuilding is an ancient sport with modern day popularity. The sport has evolved over the centuries to its modern version, where participants are judged not by objective feats of exertion, but subjectively based on their physique. Routine poses are performed, where bodybuilders are critiqued on muscularity, leanness and symmetry. The preparation for a bodybuilding contest typically consists of an extended off-season where participants aim to gain muscle mass and thus achieve a high degree of muscularity, followed by the in-season period commonly highlighted by a strict diet and training regimen, aimed at reducing body fat whilst maintaining muscle mass to achieve an extremely lean yet muscular physique. A branch of bodybuilding which has become increasingly popular is natural bodybuilding, where participants are screened for use of appearance and performance enhancing drugs and are required to rely solely on exercise and diet to achieve their physique goals.

Evidence supports the use of diet and exercise to achieve weight loss in clinical and athletic populations. Although this weight loss is primarily through loss of fat mass, a portion of this loss, particularly in already lean individuals, can be lean mass. Lean mass is metabolically active, and reductions in lean mass, as well as total mass, through periods of energy deficit are known to reduce resting metabolic rate. Additionally, a continued negative energy balance decreases anabolic and anorexigenic hormones, and increases orexigenic hormones. Consequently, further reductions in fat mass is limited, and fat mass deposition is promoted, by these physiological responses.

Muscle dysmorphia is an increasingly recognised psychiatric disorder, recently included in the Diagnostic and Statistical Manual of Mental Disorders as a form of body dysmorphic disorder. It is most centrally characterised by a distorted self-perception, whereby the individual believes themselves to be small and weak, often despite well-developed

muscularity, and a concomitant pathological drive for muscularity and leanness. In individuals with muscle dysmorphia, attitudinal and behavioural symptoms echo these characteristics. Meticulous exercise and dietary practices are devised and fastidiously monitored to achieve a mesomorphic body, while deviation from either food or exercise regimen is associated with marked anxiety. Due to the implicit overlap between muscle dysmorphia and bodybuilding in regards to the pursuit of a muscular and lean body, the two have often been conflated. Therefore, it remains pertinent to differentiate between muscle dysmorphia and a non-pathological pursuit of muscularity.

Despite the growing popularity of bodybuilding, the literature examining this population remains scarce and dated, with a large proportion of studies in bodybuilders having investigated health outcomes associated with use of anabolic steroids. The diet of bodybuilders has been rarely examined since the 1990's, and only a small number of studies, primarily case studies, have documented the effects of training and diet on physiology during competition preparation. Bodybuilders are known to achieve extremes of body composition, however the strategies used to achieve this outcome, and the physiological effects of these strategies, remain under described. Moreover, studies of muscle dysmorphia in bodybuilders are limited in number and depth. Hence, this thesis aimed to add to the current body of topic-related research by: (1) systematically reviewing muscle dysmorphia symptomatology in bodybuilders and non-bodybuilder resistance trainers; (2) deconstructing the inference that bodybuilding and symptoms of muscle dysmorphia are synonymous by identifying correlates of muscle dysmorphia symptomatology in natural bodybuilders; (3) examining the dietary strategies used by experienced natural bodybuilders, and pertinently, the purported rationale behind these strategies; and (4) describing the body composition, physiology, and psychology responses to the dietary and training practices employed by male natural bodybuilders during the preparation and recovery from a bodybuilding competition.

A systematic search of the literature found 31 studies that measured muscle dysmorphia symptomatology using a validated questionnaire in bodybuilders or non-bodybuilder resistance trainers. Findings from the systematic review indicated muscle dysmorphia symptomatology was greater in bodybuilders than non-bodybuilder resistance trainers (effect size (ES) = 0.53-1.12; $p \leq 0.01$). Evidence supported muscle dysmorphia symptoms were higher in competitive bodybuilders than non-competitive bodybuilders (ES = -1.09-1.42; $p < 0.001$). Symptoms of muscle dysmorphia were associated with anxiety, depression, neuroticism, perfectionism, and low self-esteem. It remains unclear whether these characteristics are exacerbated by bodybuilding, or whether individuals with these characteristics are attracted to the bodybuilding environment.

Following on from the systematic review, a cross-sectional survey study was conducted to assess muscle dysmorphia and eating disorder symptoms, and identify correlates of muscle dysmorphia symptomatology in male, natural bodybuilders. The primary aim was to deconstruct the inference that bodybuilding and symptoms of muscle dysmorphia are synonymous. The survey was completed by 99 participants, of which 60 were eligible for inclusion. Regression analysis identified the rate at which bodybuilders lose weight during preparation ($\beta = 0.307$), and eating disorder symptoms ($\beta = 0.298$), were both positively correlated with muscle dysmorphia symptomatology, while bodybuilding experience ($\beta = -0.257$) was negatively associated with muscle dysmorphia symptomatology. The model explained 20.8% of the variation in muscle dysmorphia symptoms. These results suggest it is the presence of disordered eating psychopathology that may differentiate between bodybuilders with and without muscle dysmorphia symptomatology. Extending on this, the results suggest that those bodybuilders who lose weight more rapidly during competition, which may indicate pathological eating behaviours, may be more likely to display muscle dysmorphia symptoms. If bodybuilding participation is unable to appease muscularity related symptoms in individuals displaying features of muscle dysmorphia, long-term participation is unlikely. Such a scenario may explain the negative association identified between bodybuilding experience and muscle dysmorphia symptomatology. An alternative explanation for this negative association may be that participation in bodybuilding has a protective effect, whereby muscle dysmorphia symptoms are reduced with continued participation.

To examine the dietary strategies used during competition preparation, the third study of this thesis used a qualitative study design, where in-depth interviews were performed with seven experienced, male natural bodybuilders. In particular, the rationale behind the use of the dietary strategies was discussed, as were the sources of dietary education used by bodybuilders. The off-season period was highlighted by large, frequent meals containing high amounts of protein with adequate carbohydrate to permit high training loads and achieve muscle gain. Energy intake was progressively reduced during the in-season via a reduction in carbohydrate and fat intake to assist in loss of body fat. To off-set declines in metabolic rate and fatigue, weekly re-feed days with higher carbohydrate were included. In the final "peak week" before competition, more specific strategies were adopted including fluid and sodium manipulation and carbohydrate loading to achieve the leanest possible physique. Dietary restriction gave way to disinhibition or discrete eating binges post-competition. These bodybuilders reported the use of predominantly evidence based strategies. Additionally, novel strategies such as weekly re-feed days to enhance fat loss, and sodium and fluid manipulation, warrant further investigation to evaluate their efficacy and safety.

To extend on the dietary strategies described in Study 3, a longitudinal observational study was conducted, which examined the body composition and physiological responses to competition preparation and recovery. Nine competitive natural bodybuilders (29.0 ± 9.5 yrs, 83.7 ± 8.9 kg, and 6.0 ± 6.6 years bodybuilding experience) were assessed on three occasions before the contest, and once after the contest. Measures included body composition (dual energy x-ray absorptiometry, bioelectrical impedance analysis, anthropometry), resting metabolic rate, blood parameters, and food and training diaries. A significant reduction in fat mass occurred during the pre-contest period (mean reduction = 3.5 kg, d = 1.3), while only a small reduction in lean mass occurred during the final 8 weeks of contest preparation (mean reduction = 0.9 kg, d = 0.1). Despite reductions in total and fat mass, no significant changes in the resting metabolic rate of participants were identified, which may reflect the relative maintenance of lean mass during preparation. The success of the participants in reducing fat mass, while still maintaining lean mass and metabolic rate is likely attributed to the high protein intake and regular high intensity resistance training. Large reductions in total serum testosterone, free serum testosterone, and serum insulin-like growth factor-1 were found during the pre-contest period (mean reduction = 38.0%, d = 1.6; mean reduction = 50.3%, d = 1.5; mean reduction = 26.2%, d = 0.9, respectively). Interestingly, no changes were detected in cortisol, insulin, leptin or adiponectin. Five participants dropped below the reference range for serum testosterone concentration during the pre-competition period, indicating that despite relative maintenance of lean mass and metabolic rate, participants progressed to an anti-anabolic state.

In order to extend the findings of Studies 1 and 2, muscle dysmorphia, disordered eating, and physique perception were assessed on five separate occasions during the 16 week pre-competition period in the longitudinal study. Muscle dysmorphia, disordered eating, and fat and muscle perception were shown to remain constant throughout the pre-competition period, despite significant changes in body composition, most notably reduction in fat mass. Furthermore, greater muscle dysmorphia symptomatology in the early periods of preparation was associated with a subsequently greater reduction in energy and fat intake. These findings suggest there may be a distinct disconnect between actual body composition and attitudes towards muscularity.

Outcomes of this series of studies identify the nutritional and dietary strategies employed by bodybuilders during the competition preparation cycle. Muscular hypertrophy is reported to be achieved during the off-season through the application of progressive resistance training coupled with high energy and protein intake. During the in-season, it was identified that fat mass is progressively reduced through diet and training manipulations, resulting in the achievement of extremely low fat mass, often to the extremes of known body fat levels. Using this approach, bodybuilders in this cohort were also successful at maintaining lean mass during this period of negative energy balance, despite reductions in anabolic hormones. Resting metabolic rate changes may vary, however in this cohort no significant changes were discovered, suggesting the maintenance of lean mass and resistance training volume may prevent adaptive downgrades in resting metabolic rate during periods of prolonged energy deficit. The systematic review and cross-sectional studies highlighted that muscle dysmorphia symptoms may be present in the bodybuilding population; however, not all bodybuilders display these symptoms. Hence, it is not the activity of bodybuilding itself that is a pathological endeavour, rather, the context of bodybuilding may attract those susceptible to the development of muscle dysmorphia symptoms. Particular behaviours, such as rapid reductions in body weight, and pathological eating habits, may predict muscle dysmorphia symptoms in bodybuilders. The outcomes of this series of studies must be considered with the limitation of the small sample size included, therefore caution is required when drawing such conclusions with the broader bodybuilding population.

The findings of this thesis suggest several identified strategies are worthy of further investigation. The maintenance of lean mass during a prolonged period of energy restriction described in Study 3 is likely attributed to the use of a high protein diet in addition to intense resistance exercise. Further examination of these strategies in bodybuilders, and in other population groups, including athletes aiming to reduce body fat for competition, may provide detailed evidence for their efficacy and recommended use. The use of a re-feed day, or intermittent fasting, and hormonal and metabolic responses associated with short-term energy restoration, warrant investigation to determine benefits for weight loss whilst maintaining lean mass in both lean athletic and obese populations. Further corroboration of the correlates of muscle dysmorphia symptoms identified in this set of studies is required. Examination of these correlates in a broader population group, including individuals displaying greater muscle dysmorphia symptomatology, may add evidence to the debate over the nosological classification of muscle dysmorphia. Ongoing longitudinal research into muscle dysmorphia is required to confirm the findings described in Study 3.

PUBLICATIONS ARISING FROM THIS THESIS

Published manuscripts:

1. Mitchell L, Murray SB, Cobley S, Hackett D, Gifford J, Capling L, O'Connor H. Muscle dysmorphia symptomatology and associated psychological features in bodybuilders and non-bodybuilder resistance trainers: A systematic review and meta-analysis. *Sports Med* 2017; 47(2): 233-259. https://doi.org/10.1007/s40279-016-0564-3
2. Mitchell L, Murray S, Hoon M, Hackett D, Prvan T, O'Connor H. Correlates of muscle dysmorphia symptomatology in natural bodybuilders: Distinguishing factors in the pursuit of hyper-muscularity. *Body Image* 2017; 22: 1-5. http://dx.doi.org/10.1016/j.bodyim.2017.04.003
3. Mitchell L, Hackett D, Gifford J, Estermann F, O'Connor H. Do bodybuilders use evidence-based nutrition strategies to manipulate physique? *Sports* 2017; 5: 76. https://doi.org/10.3390/sports5040076
4. Mitchell L, Slater G, Hackett D, Johnson N, O'Connor H. Physiological implications of preparing for a natural male bodybuilding competition. *Eur J Sport Sci* 2018; In Press. https://doi.org/10.1080/17461391.2018.1444095

Conference presentations – oral:

5. Mitchell L, Murray S, Hoon M, Hackett D, Prvan T, O'Connor H. Behavioral predictors of muscle dysmorphia symptomatology in natural bodybuilders. *Med Sci Sport Exer* 2017; 49(5S): 201. https://doi.org/10.1249/01.mss.0000518793.83710.8e

Conference presentations – poster:

6. Mitchell L, Cobley S, Hackett D, Gifford J, Capling L, Murray SB, O'Connor H. Muscle dysmorphia symptoms in bodybuilders and non-bodybuilder resistance

trainers, and associated psychological characteristics: A systematic review and meta-analysis. *Med Sci Sport Exer* 2016; 48(5S): 892. https://doi.org/10.1007/s40279-016-0564-3

OTHER PUBLICATIONS DURING CANDIDATURE

Published manuscripts:

1. Spendlove J, Mitchell L, Gifford J, Hackett D, Slater G, Cobley S, O'Connor H. Dietary intake of competitive bodybuilders. *Sports Med* 2015; 45(7): 1041-63. https://doi.org/10.1007/s40279-015-0329-4
2. Amirthalingam T, Mavros Y, Wilson GC, Clarke JL, Mitchell L, Hackett DA. Effects of a modified German volume training program on muscular hypertrophy and strength. *J Strength Cond Res* 2017; 31(11): 3109-19. https://doi.org/10.1519/JSC.0000000000001747
3. Hackett, DA, Armithalingam T, Mitchell L, Mavros Y, Wilson GC, Halaki M. Effects of different high volume resistance training programs on muscle strength and hypertrophy. *Sports* 2018; 6(1): 7. https://doi.org/10.3390/sports6010007

CHAPTERS OF THIS THESIS PUBLISHED AS MANUSCRIPTS

The work presented in Chapter 3 of this thesis is based on the published manuscript Mitchell L, Murray SB, Cobley S, Hackett D, Gifford J, Capling L, O'Connor H. Muscle dysmorphia symptomatology and associated psychological features in bodybuilders and non-bodybuilder resistance trainers: A systematic review and meta-analysis. *Sports Med* 2017; 47(2): 233-259. I co-designed the study with the co-authors, collected the data with assistance from L. Capling, interpreted the data with S. Murray, and wrote the drafts of the manuscript.

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The work presented in Chapter 5 of this thesis is based on the published manuscript Mitchell L, Hackett D, Gifford J, Estermann F, O'Connor H. Do bodybuilders use evidence-based nutrition strategies to manipulate physique? *Sports* 2017. 5: 76. I co-designed the study with the co-authors, collected the data with assistance from H. O'Connor and D. Hackett, analysed the data with assistance from F. Estermann, and wrote the drafts of the manuscript.

The work presented in Chapter 6 of this thesis is based on the published manuscript Mitchell L, Slater G, Hackett D, Johnson N, O'Connor H. Physiological implications of preparing for a natural male bodybuilding competition. *Eur J of Sport Sci* 2018; In Press. I co-designed the study with the co-authors, collected the data, analysed the data, and wrote the drafts of the manuscript.

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As supervisor for the candidature upon which this thesis is based, I can confirm that the above authorship attribution statements are correct.

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Date 19/2/2018

CHAPTER 1.

Introduction

INTRODUCTION

The popularity of bodybuilding has consistently grown throughout the previous decades [1]. The expansion of the sport in the 1970's to include drug-tested contests, and the addition of less extreme physique categories such as fitness and muscle model, as well as the broader inclusion of female athletes, has seen competition participation numbers continue to increase worldwide [1]. Additionally, bodybuilding practices have become more common in the general population, with the benefits of dietary manipulation and resistance training for wider sports performance as well as general health benefits now increasingly recognised [2-8].

Competitive bodybuilders (BB) are judged on their muscularity and leanness, and employ structured diet and exercise regimens to achieve the ideal competition physique [9,10]. A long-term approach to competition preparation is taken. An extended off-season aiming to achieve muscular hypertrophy and thus a high degree of muscularity is followed by an in-season period aimed at reducing fat mass while maintaining muscle mass. Early research into these athletes suggested a high energy and protein intake was typically consumed. To reduce body fat levels the in-season period leading to competition, it has been reported that a reduction in energy intake occurs, commonly through the implementation of a low fat diet and a reduction in carbohydrate intake [10]. Previous evidence has suggested a high volume resistance training schedule is implemented throughout the off-season and in-season to build and maintain muscle mass, while aerobic exercise is incorporated into the training regimen in the months leading to competition to assist in reduction of body fat [9].

More recent research into the practices of modern BB has been limited. Case studies have documented individual dietary and training routines of natural BB, with the inclusion of hormonal and metabolic responses. Large reductions in total body, fat and lean mass have been shown to coincide with competition preparation. General reductions in anabolic and orexigenic hormones have been described, along with reductions in resting metabolic rate (RMR) [11-13]. However, case studies may be limited in their generalisability to the broader bodybuilding community.

In addition to the physiological parameters which have been investigated in BB, several body image-related conditions have been the focus of research. Muscle dysmorphia (MD), a psychiatric disorder characterised by a self-perception of inadequate muscularity and subsequent obsessive behaviours focussed on increasing muscle mass and leanness [14], has been increasingly recognised. Due to the contextual similarities between bodybuilding and MD, BB have been the primary population in which MD has been examined, as well as strength based athletes such as powerlifters [15]. It has been estimated that 10% of studied males display MD symptoms [16]. It has yet to be determined if the sport of bodybuilding increases the risk of developing MD symptoms, or if the sport of bodybuilding attracts those at risk of, or already displaying MD symptoms. Indeed, the sport of bodybuilding itself has been described as a pathological habit, leading to a potentially greater incidence of MD in BB than other population groups, including strength-trained athletes [15]. At this stage though, it is unconfirmed whether MD symptomatology is greater in BB than non-bodybuilder resistance trainers (NBBRT). Further, it is unknown whether MD symptoms are influenced by competition preparation. It has been demonstrated that an acute training session can reduce MD symptoms [17], however no longitudinal measures have been performed in BB. Given the high degree of muscularity and extreme leanness achieved in competition preparation, it is reasonable to hypothesise that symptoms of MD would reduce as individuals move closer to their ideal physique. However, it is also possible for the ideal physique to become increasingly extreme as body fat levels reduce, resulting in a cycle of increased symptoms and further extreme behaviours.

Despite the popularity of the sport of bodybuilding, and the success achieved by these athletes in modifying their body composition, recent studies into training and dietary practices employed by BB are generally limited to small cohorts and case studies. Preparation strategies employed by BB remain largely undocumented, while there is limited evidence for the changes in metabolism and physiology which coincide with the body composition modification in this population group. Furthermore, the body image related changes which accompany these body composition shifts are yet to be determined.

THESIS AIMS

The primary aim of this thesis was to examine dietary and exercise practices of male natural BB, and assess the physiological and psychological effects of these practices. This thesis contains a series of studies that describe the dietary and training protocols used by this target population during preparation and recovery from bodybuilding competition. Changes in body composition, physiology and body image related concerns which take place during this period of time are also assessed. Approaches including in-depth interviews, food and training diaries, direct physiological measures of metabolism and hormones, and self-report questionnaires, were used to achieve the following specific aims of each study:

1. systematically review and compare evidence of MD symptomatology in BB and NBBRT, and identify psychological features associated with MD in these populations;
2. identify correlates of MD symptoms in male, competitive natural BB;
3. identify and describe the dietary and supplement strategies used by experienced natural BB during a competitive season, and their purported rationale;

4. assess the body composition and physiological changes that occur during preparation and recovery from a natural bodybuilding competition; and
5. assess changes in MD and disordered eating symptoms during preparation for a natural bodybuilding competition.

SPECIFIC HYPOTHESES

1. Bodybuilders will present greater MD symptomatology than NBBRT.
2. Eating disorder symptoms will be associated with increased MD symptoms, but not a non-pathological pursuit of muscularity (that is, bodybuilding).
3. Drug-free BB will follow structured, strict and periodised dietary and exercise protocols during preparation for competition, some of which may have limited or no evidence base. Energy intake will be progressively reduced as competition approaches.
4. Fat mass will significantly reduce during competition preparation, with concomitant reductions in lean mass. Metabolic rate and anabolic hormones will reduce in conjunction with these body composition changes.
5. Competition preparation will ameliorate MD and disordered eating symptoms.

SIGNIFICANCE OF THIS RESEARCH

The dietary and training habits of modern BB are largely undocumented. Outcomes from this research will provide greater insight into the methods used during competition preparation by natural BB which can be used by health practitioners such as dietitians to provide advice and recommendations, and also to further research in the fields of diet and exercise in weight category sports. This research may also serve to uncover novel strategies used by BB to achieve their body composition outcomes which as yet remain undocumented in literature. Such strategies may warrant further research with the potential of providing recommendations for other population groups, especially for the development of lean mass and reduction in body fat.

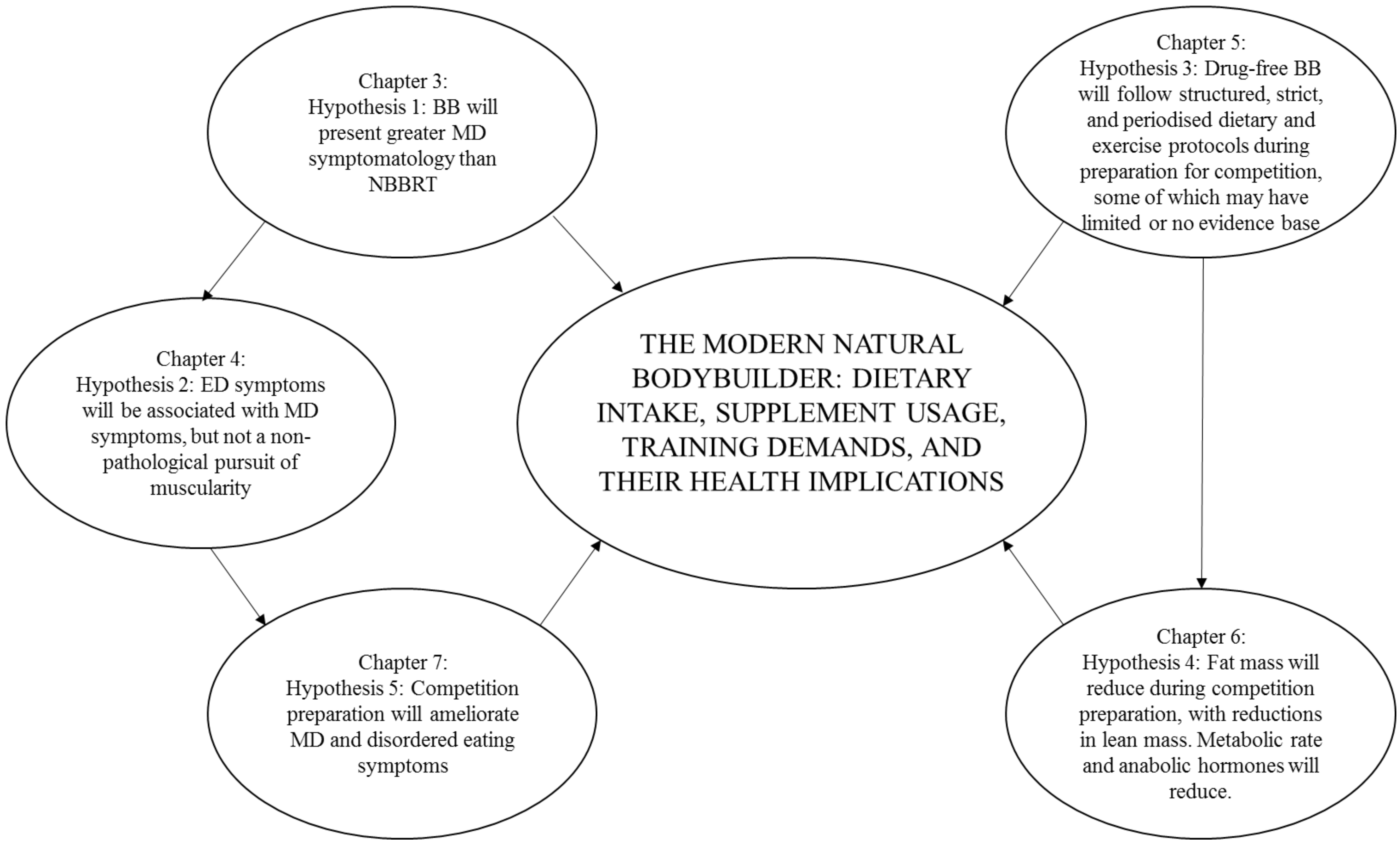

Figure 1.1. Diagrammatic description of the Chapter structure of this Thesis, including Hypotheses addressed in each Chapter.

CHAPTER 2.

Background Literature

LITERATURE REVIEW

Introduction to bodybuilding

Bodybuilding has long been considered a niche sport, with extreme body composition outcomes matched by extreme preparatory behaviours. However, in recent decades, mainstream popularity of the sport has increased, reflected by the increased participation numbers [1]. Competitive BB are judged on their physique while performing a routine set of physical poses with success based on muscular size, symmetry and definition [9]. A fastidious pursuit of muscularity is often seen amongst BB, who have been shown to commit to a rigorous training regimen, coupled with a strict diet and supplement program [10]. Appearance and performance enhancing drugs such as anabolic androgenic steroids (AAS) may also be used by BB to achieve body composition goals [18,19].

Bodybuilders undertake a long-term approach to prepare for competition. The primary off-season goal is to build muscle mass, with less of a focus on fat mass. Training and dietary approaches are matched with this hypertrophic pursuit. The in-season goals shift to a gradual reduction in fat mass, whilst attempting to maintain muscle mass. This is reportedly achieved through a progressive reduction in energy intake, intense resistance training, and an increase in aerobic exercise [1,10].

History of bodybuilding

Modern bodybuilding is reported to have commenced in the late 1800's with Eugen Sandow, a Prussian born physical culturist recognised as the "father of modern bodybuilding" [20]. Sandow was the first strongman to combine demonstrations of great strength with staged displays of his so called "exquisite", lean and muscular physique [20]. Although Sandow pioneered the idea of "muscle display performances", analogous to current day posing routines used by BB, it was the Vaudeville promoter Flo Ziefgfeld who recognised the wider commercial potential of showcasing Sandow's muscular and proportioned body as a top billing stage act [20]. Ziefgfeld recognised that audiences were just as captivated with Sandow's appearance as his strength. Sandow eventually went on to start his own gymnasium, bodybuilding magazine, and write training manuals on bodybuilding [20].

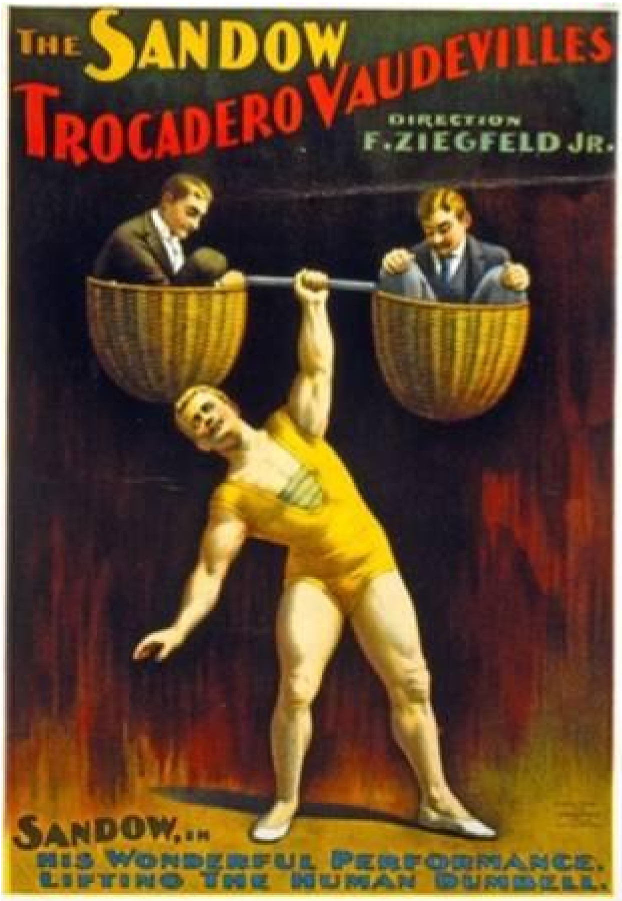

Figure 2.1. An advertisement for "The Sandow Trocadero Vaudevilles" performance, circa 1894. Source www.art.com

The popularity of muscularity displays increased through Sandow and his successors. Combined with the development of interest in physical activity from a health perspective in the mid-19th century, the muscular physique became an ideal which was a popular aspiration [20]. Spectators were no longer outside observers, rather they had an interest and capacity to be potential participants [20]. As the sport of bodybuilding emerged, comparisons between participants became inevitable. With this, a number of set poses were developed as a means of directly comparing bodybuilding participants [20].

By the 1950's, the first supplements tailored for athletes came into wider use [21]. Although different diet approaches were still emerging, protein foods and supplements became a major emphasis in bodybuilding from the 1950's [21]. Notably, also around this time another important development was the emergence of AAS which were the first of a range of other drugs (e.g. insulin, insulin-like growth factor 1, growth hormone) available to BB to push the boundaries on muscle development and definition [22].

In the late 1970's, bodybuilding widened its scope to incorporate a drug free, natural bodybuilding competition [23]. This change was prompted by concerns about the negative health effects of drug use in bodybuilding [23]. The physiques of competitors had also reached such an extreme that they were no longer aesthetically pleasing to a wider audience resulting in a downturn in participant and spectator popularity [20]. The introduction of other, less extreme in muscularity bodybuilding categories has followed (e.g. figure/physique, sports/fitness, and swimsuit/bikini). In 2013, the Mr Olympia contest, regarded as the most prestigious bodybuilding competition, introduced a physique category for men, one which aims to attract competitors with less extreme physiques and more consistent with the ethos of the Grecian ideal for which historically bodybuilding seeks to replicate. Higher participation of women, especially in newer bodybuilding categories, is evident [24]. The popularity of natural bodybuilding is rapidly increasing. In 2013, over 200 amateur natural bodybuilding contests took place in the United States, with this number expected to increase annually [1].

Bodybuilding competition

Bodybuilding competitors are allocated into categories based on height, weight, or age. BB competing in natural federations are randomly selected to undergo urine tests for use of banned substances. In Australian federations, the Australian Sports Anti-Doping Authority is responsible for implementing the World Anti-Doping Code, with competitors subject to The Code and Prohibited List developed by the World Anti-Doping Agency [25]. Competitors are judged in two rounds – the muscularity and the symmetry rounds. In the muscularity round, competitors complete a routine of set poses to display their muscularity and leanness. In this round, judges compare competitors based on muscularity – the shape, thickness and quality of muscle; proportion – the balance of one muscle group to another; definition – muscle separation, definition and vascularity; and balance – left side of the body compared to the right, front of the body compared to the rear [26]. In the symmetry round competitors stand before the judges and are observed from four angles – the front, each side, and the rear. In this round judgement is based on structural flaws – faults within the competitor's skeletal structure; proportion – the balance of one muscle group to another; balance – the left side of the body compared to the right, the front of the body compared to the rear; and symmetry – the competitor's overall shape and line [26].

Diet and bodybuilding

The dietary intake of BB has been reported as structured and periodised [10]. Specific energy and macronutrient targets are commonly followed during each phase of competition preparation. During the off-season BB typically focus on increasing muscle mass, with less regard to body fat levels. Their dietary intake reflects this, with previous reports demonstrating overall energy intake to be high, with high volumes of protein, fat and carbohydrate consumed. A recent systematic review reported the highest energy and protein intakes occurred during the off-season. Similarly, carbohydrate and fat intakes were highest during this period [10]. The in-season focus shifts to reducing fat mass whilst maintaining muscle mass. Dietary patterns are reported to shift with this change in focus. In order to achieve fat loss, BB report a reduction in energy intake during the in-season, with carbohydrate and fat intake substantially lower than off-season values [10]. In contrast, case studies and a systematic review suggest protein intake remains similar to intakes during the off-season [10,11,13]. During this competition preparation period, BB have been shown to monitor their intake through the use of food diaries and food scales, to ensure energy and macronutrient goals are met [11]. The post-competition period is less structured than the in-season. Case studies have demonstrated food intake to be less routinely monitored, with less concern shown for energy and macronutrient targets [13]. Total energy intake is greatly increased in the immediate post-competition period [27], with body weight typically increasing. On the day of competition, a group of 45 male BB self-reported a typical weight regain after competition of 5.9 kg [28], while in a prospective study, a small group of female BB demonstrated on average a 3.9 kg increase in body weight in the three weeks post-competition [27]. Although the dietary intake of BB has been described [10], the majority of this evidence is dated, with few studies published in recent years. As such, the dietary habits of modern BB remains largely undocumented.

Dietary supplements are synonymous with bodybuilding. Supplements aimed to aid accumulation of muscle mass, improve exercise performance, and complement usual dietary intake are used [9]. In a previous sample of 127 male BB, a self-report survey showed all participants consumed dietary supplements [9]. On average 3.4 ± 0.9 supplements were used during the off-season, and 3.7 ± 1.2 supplements were used during the six weeks pre-competition. The most popular supplements used during the off-season were protein shakes, creatine, branched chain amino acids and glutamine. Similar supplements were most popular during the pre-competition period, with the addition of ephedrine-containing/caffeine-containing products [9].

Training regimens of bodybuilders

Empirical literature regarding the training routines of BB is scarce. The exercise routine of BB is reported to reflect their specific, periodised goals. A cross-sectional, self-report survey of 127 competitive male BB showed that during the off-season, a time committed to muscular hypertrophy, BB typically use a high volume resistance training program, with very low volumes of aerobic exercise. A split routine is commonly adopted, whereby each training session focuses on specific muscle groups [9]. Four to five sessions were reported to be performed per week, allowing each muscle group to be trained once or twice per week [9,11,13]. The set and repetition range target hypertrophy, with most BB performing 7-12 repetition maximum (RM) for 3-6 sets per exercise, and 4-5 exercises per muscle group [9].

As BB progress into their in-season, training routines shift to reflect the goal of reducing fat mass while maintaining muscle mass. Small modifications are typically made to the resistance training program, including reductions in set number to 3-4 sets per exercise, and an increase in repetitions to 7-15 RM per set [9]. The resistance training protocol aims to maintain muscle mass despite remaining in a long-term energy deficit. To aid fat loss, it is common for aerobic training to be significantly increased. A combination of high intensity interval training, and low to moderate intensity steady state exercise was implemented in a large group of competitive male BB during the in-season [9]. Frequency of aerobic training varies during the in-season, with greater than five sessions per week reported [9,11]. In addition to resistance and aerobic training, case studies show BB commonly incorporate posing practice into their regimen during the in-season preparation [12]. This involves repeatedly holding isometric contractions of the major muscle groups for 30-60 seconds while the limbs and torso are in a position intended to make the muscles appear large and defined [13].

Body composition changes in bodybuilding

BB achieve significant changes in body composition during competition preparation. Although the weight of each individual competitor varies based on their competition weight category, all participants follow a similar trend of increasing lean mass in the off-season, then subsequently reducing total mass, primarily in the form of fat mass, during the in-season [1]. These reductions in fat mass allow BB to reach the extremes of body composition. Several cohort studies have described the changes in body composition during competition preparation. Based on surface anthropometry and hydrodensitometry measures, a 3.8 kg reduction in fat mass was reported during competition preparation in a small group of male BB, with a mean reduction in lean mass of 1.6 kg [29]. Similarly, male BB assessed 10 weeks and five days prior to competition using hydrodensitometry and dual-energy x-ray absorptiometry (DXA) lost on average 6.9 kg of total body mass, with fat mass accounting for 4.5 kg (64% of total mass lost) [30]. More recently, case studies have documented significant reductions in fat mass, with concomitant reductions in lean mass, during competition preparation of male natural BB. In some cases, lean mass accounted for 43% of total mass lost [11-13]. Further cohort studies in modern BB are required to corroborate these case study findings.

Adaptive responses to energy restriction (Effects of weight loss on metabolism, energy expenditure and hormones)

Total energy expenditure is a combination of three factors – the resting metabolic rate (RMR), the thermic effect of food, and the energy expenditure of activity (Figure 2.2). The energy expenditure of activity can be further divided into exercise activity thermogenesis and non-exercise activity thermogenesis [31]. The RMR is by far the greatest component of total energy expenditure, with approximately 60% of energy expended accounted for by the RMR [32]. The RMR is influenced by total mass, and its constituent components of fat mass and fat free mass.

A reduction in fat mass through restriction in energy intake is suggested to be detected by the body through a series of neuroendocrine pathways. This reduction initiates adaptive processes which have the effect of preventing further reductions in stored body fat. One such process is a reduction in metabolic rate beyond those decreases accounted for by changes in fat mass and fat free mass. This is termed adaptive thermogenesis [33,34], and it has been suggested that the greater the energy deficit and reduction in body fat, the greater the reduction in RMR [33].

Maintenance of the reduced body weight is opposed by this adaptive thermogenesis, which has been shown to reduce the magnitude of the negative energy balance. Reductions in sympathetic nervous system (SNS) tone and increases in parasympathetic nervous system tone have been associated with the reduced body weight [32]. These changes in autonomic nervous system tone may account for a significant fraction of the hypometabolic state through direct effects on skeletal muscle, and/or indirectly through effects on circulating thyroid hormones [32].

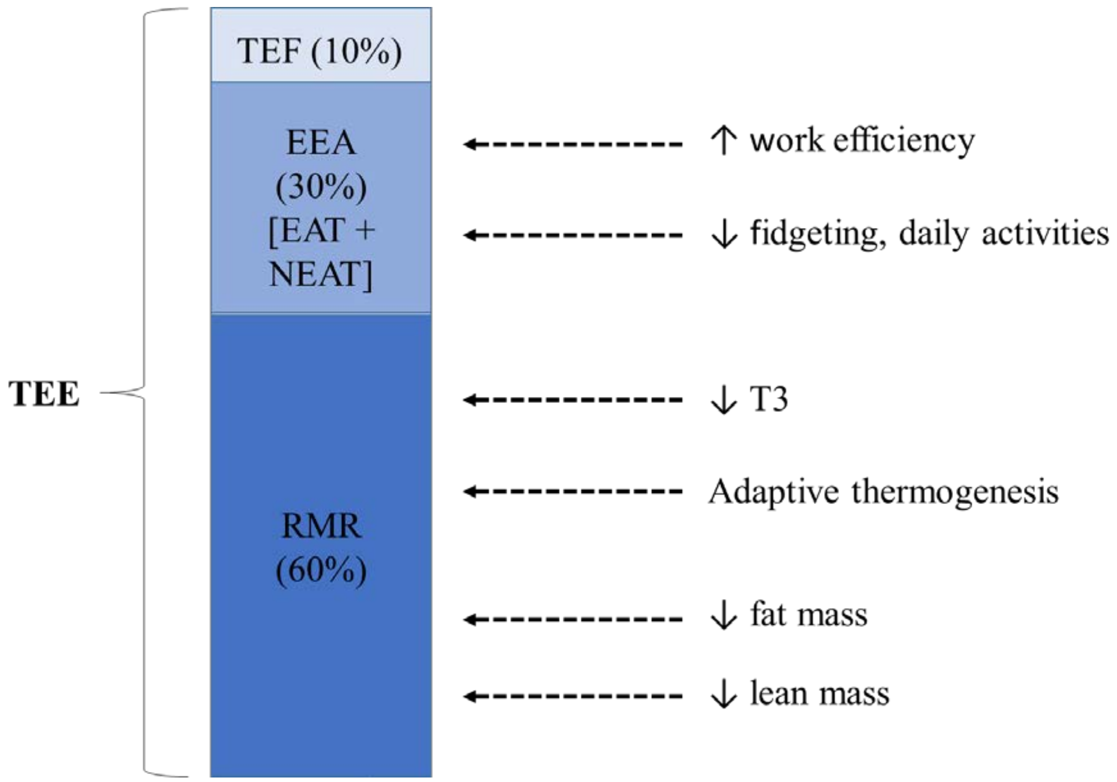

Figure 2.2. Components of total energy expenditure (TEE), and the physiological and behavioural responses to energy restriction which reduce TEE. A reduction in fat mass and lean mass resulting from continued energy restriction reduces RMR directly through a reduction in metabolically active tissue [32, 33]. Total reduction in RMR is typically greater than that which can be predicted based on reductions in tissue mass, a phenomenon referred to as adaptive thermogenesis [32]. Reductions in thyroid hormones, in particular T3, occur during energy restriction, causing a reduction in thermogenesis and metabolic rate [35, 36]. Energy restriction results in a reduction in energy expenditure of activity (EEA) through reductions in non-exercise activities, such as fidgeting [36], while the energy cost of activity is reduced through an increase in work efficiency [31, 40]. Dotted line indicates a reducing effect. Expenditure values are approximate. EAT, exercise activity thermogenesis; EEA, energy expenditure of activity; NEAT, non-exercise activity thermogenesis; RMR, resting metabolic rate; T3, triiodothyronine; TEE, total energy expenditure; TEF thermic effect of food.

Thyroid hormones, particularly triiodothyronine (T3), play an important role in regulating metabolic rate. Circulating thyroid hormones have been shown to reduce during energy restriction, leading to a reduction in thermogenesis and overall metabolic rate [35,36]. Testosterone and insulin-like growth factor 1 (IGF-1) are typically reduced during energy restriction, signalling an anti-anabolic effect. This signal likely promotes fat deposition and the loss of lean mass [35].

Hormonal responses to energy restriction extend their effects to appetite and food intake. Leptin is a hormone secreted primarily from adipose tissue, and has been demonstrated to signal the amount of fat stored in adipocytes [37,38]. Reductions in body fat resulting from energy restriction reduces circulating leptin levels. Evidence suggests the reduced leptin concentration stimulates an increase in appetite through expression of orexigenic and inhibition of anorexigenic neuropeptides from the hypothalamus [37]. Orexigenic neuropeptides under control of leptin include Agouti-related protein (AgRP) and neuropeptide Y (NPY). Anorexigenic neuropeptides under control of leptin include proopiomelanocortin (POMC) and corticotropin-releasing hormone (CRH) [37]. Ghrelin is an appetite stimulating hormone secreted from the stomach to indicate short term energy availability. Levels have been shown to be increased in periods of hunger and pre-prandial, and reduced post-prandial. During periods of weight loss and energy restriction, increased circulating ghrelin concentrations have been demonstrated. Ghrelin stimulates neurones expressing NPY and AgRP, and has an inhibitory effect on POMC and CRH neurones. Through these effects, the increased concentrations of ghrelin resulting from energy restriction may function to stimulate appetite and food intake after weight loss [37]. It is suggested that the changes in leptin and ghrelin concentrations, and the resultant neuropeptide expression, work in coordination to defend body weight and stimulate appetite during periods of energy restriction and weight loss [39].

The energy expenditure of activity is also modified as a result of energy restriction and weight loss. Reductions have been seen in non-exercise activity thermogenesis, such as fidgeting and daily activities, after weight loss [36]. In addition to reduced activity, increases are observed in work efficiency. Less energy may be expended for the same amount of work, thereby reducing the energy cost of activity [31,40]. The mechanisms behind these reductions in activity and increased work efficiency are suggested to be similar to those involved in altered appetite and food intake during energy restriction. Sensory information regarding availability of food and energy are mediated in the hypothalamus, in particular the arcuate nucleus, where two important cell types are located [31]. Cells containing orexigenic peptides such as NPY and AgRP, and cells containing anorexigenic peptides such as POMC and cocaine- and amphetamine-regulated transcript (CART) are located in this hypothalamic region. Leptin acts on the hypothalamus to increase anorexigenic neuropeptide expression, which may increase physical activity and reduce work efficiency [31]. Conversely ghrelin acts on the hypothalamus to increase orexigenic neuropeptide expression, which may decrease physical activity and increase work efficiency [31]. During periods of energy restriction and weight loss, leptin concentrations are reduced and ghrelin concentrations are increased, mediating this reduced energy expenditure [31]. This reduced energy expenditure opposes the change in body weight [31], and is supported by the autonomic nervous system, in particular the SNS for which suppressed activity has been shown during energy restriction [41]. At the skeletal muscle level, increased work efficiency appears to be in part associated with uncoupling proteins, some of which show reduced expression during energy restriction [42].

Evidence supports altered autonomic nervous system output during energy restriction and weight loss. Specifically, reduced SNS activity has been shown, evidenced by reduced circulating catecholamine concentration, increased heart rate variability, reduced muscle sympathetic nerve activity and reduced heart rate [41]. Leptin acts to stimulate SNS activity, while NPY acts to reduce SNS activity. Reduced leptin and increased NPY concentrations associated with energy restriction and weight loss may hence reduce overall SNS activity [41]. Reduced SNS activity in part mediates the reduction in RMR associated with energy restriction and weight loss. Reduced SNS activity may also act to increase food intake [41]. Thus alterations in SNS activity are suggested to oppose reductions in body weight by modifying the energy deficit.

The adaptive responses to energy restriction and weight loss are many, widespread and interrelated. Changes in hormone concentrations are suggested to act on the hypothalamus to stimulate hunger and food intake via expression of orexigenic neuropeptides and inhibition of anorexigenic neuropeptides. Other hormones have been shown to reduce metabolic rate, reduce lean mass and increase fat deposition. Reductions in sympathetic tone, and increases in parasympathetic tone, have been demonstrated. Behavioural changes are observed, with energy expenditure of activity decreased through a combination of reduced physical activity and an increase in work efficiency. These changes in activity energy expenditure are suggested to be instigated by similar hormone and neurone mechanisms as those which increase food intake. The combination of these interrelated processes actively opposes further reductions in body mass, by modifying the energy balance to promote weight gain.

These metabolic and hormonal adaptations have been reported in BB in a small number of cohort and case studies. Reductions in RMR were found after a 14 week competition preparation in a 21 year old male BB. During the continual energy deficit, a 6.7 kg and 5.0 kg reduction in fat and lean mass occurred, respectively, resulting in a 752 $kJ \cdot d^{-1}$ reduction in RMR [12]. Similarly, during a six month competition preparation, a 26 year old male BB reduced fat mass from 15.2 kg to 4.0 kg, and fat free mass from 87.7 kg to 84.8 kg [13]. This weight loss resulted in a 38% decrease in RMR after three months, with a further reduction to

53% of the baseline value at six months. In the three months following competition, fat mass and fat free mass increased, with RMR returning to 66% of the baseline value [13]. Hormonal changes were reported in the same case study. Circulating testosterone concentration reduced from 9.22 $ng \cdot ml^{-1}$ at six months pre-competition to 2.27 $ng \cdot ml^{-1}$ at competition. Weight regain in the three months after competition was in conjunction with an increase in testosterone to 8.7 $ng \cdot ml^{-1}$. Ghrelin and leptin concentrations showed similar but opposite trends during the six month competition preparation. Ghrelin was increased from 633 $pmol \cdot ml^{-1}$ to 882 $pmol \cdot ml^{-1}$, while leptin reduced from 2.58 $ng \cdot ml^{-1}$ to 1.36 $ng \cdot ml^{-1}$. Similarly, both insulin and T3 were reduced during the weight reduction period [13]. Due to the limited number of studies, in particular those using sample sizes greater than $n = 1$, further research is required to corroborate these findings in order to better understand the adaptive physiological responses to energy restriction and exercise in lean muscular individuals.

Psychological factors in bodybuilding

Due to the strict and often extreme nature of bodybuilding, particularly in regards to diet and exercise, certain psychological symptoms and conditions have been linked to the sport, including muscle dysmorphia (MD), and disordered eating. MD is characterised by a disturbed body image perception, whereby one believes they are small and weak, when in fact they are large and strong [14]. Associated with this is a pathological pursuit of a hyper-muscular body [43]. Individuals experiencing MD commit to extreme exercise and dietary regimens aimed at accumulating muscle mass [14,44,45], which may include dietary supplements and the use of AAS [46,47]. What differentiates MD from a non-pathological desire to increase muscle mass is the overvaluation of the ideal body shape and a disproportionate influence of one's body in determining self-worth [44]. This overvaluation and desire to increase muscularity causes clinically significant impairment or distress in daily functioning. Social and occupational engagements are often given up in order to follow exercise and diet regimens, and significant levels of anxiety are experienced when such regimens are not maintained [44]. Feelings of inadequate muscularity also produce significant anxiety, which drive the ongoing muscularity pursuit.

Muscle dysmorphia was first described in 1993 in a group of male BB who reported feeling small and weak despite being large and muscular [19]. The authors described this as "reverse anorexia" due to the similar but reverse body-related concerns and behaviours as those suffering from anorexia nervosa. The condition was later termed "muscle dysmorphia" after subsequent research, and tentative diagnostic criteria were developed based on pre-existing diagnostic criteria for body dysmorphic disorder [14]. More recently MD was identified in the diagnostic and statistical manual of mental disorders 5th edition (DSM-V) as a form of body dysmorphic disorder.

As BB follow a similarly meticulous approach to physique development as individuals with MD, it is intuitive to suggest bodybuilding as a sport and context may appeal to those exhibiting MD symptoms. Comparatively greater MD symptoms have been reported in BB than power lifters [15], fitness lifters [48], non-training individuals [49,50], and college football players [51]. As yet though, it remains unclear whether bodybuilding is a cause of MD development, or if the sport of bodybuilding attracts those predisposed to, or already displaying symptoms of, MD. Additionally, MD research is limited to cross-sectional studies, with no evidence of changes in MD symptoms over time, particularly with changes in body composition.

Sports which place a high emphasis on body shape and appearance are known to be risk factors for the development of disordered eating and eating disorders (ED) [52]. The sport of bodybuilding is no exception, with disordered eating behaviours described in both male and female BB [53,54]. However, currently evidence is unclear as to the comparative extent of disordered eating symptoms in BB. Male BB have shown an increased expression of behaviours associated with disordered eating, including perfectionism, compared to non-athletic controls [55]. Female BB have demonstrated increased bulimia symptoms compared with female weight trainers, although no differences were seen in other disordered eating behaviours [54]. Crucially though, a sample of competitive male BB displayed a psychological profile similar to that of female anorexia nervosa patients, apart from increased self-esteem and body satisfaction [56]. Despite these studies, there remains a paucity of evidence of pathological eating behaviours in competitive BB. Due to a lack of longitudinal studies, as yet evidence is limited to determine whether individuals with eating disorders, or a history of disordered eating, are drawn to bodybuilding, or if the sport fosters behaviours and attitudes associated with disordered eating.

SUMMARY

BB are suggested to commit to structured and often meticulous diet and training regimens in order to achieve the lean, muscular physique required for competition success. In doing so, BB typically experience significant reductions in fat mass with concomitant moderate to large reductions in lean mass when transitioning from off-season to competition condition. During periods of prolonged energy deficit, reductions in RMR and anabolic and anorexigenic hormones including testosterone and leptin, and increases in orexigenic hormones such as ghrelin, have been reported. These changes are an adaptive response, which may assist the body in preventing further reductions in fat mass. A limited number of studies, primarily as case studies and small cohorts, have described these physiological responses in competitive BB produced during the in-season period, where dietary and training modifications are enforced to create an energy deficit and thus achieve reductions in fat mass.

Due to the similarities in muscularity enhancing pursuits, MD has become synonymous with bodybuilding. However, due to the infancy of MD research, limited attitudinal and behavioural associates of MD symptoms have been identified. Furthermore, the temporal characteristics of MD have not been investigated in general or in a bodybuilding context. Although MD has become increasingly recognised, much is still unknown about this condition.

The popularity and participation in the sport of bodybuilding has steadily increased. However, contemporary research on the dietary and training practices of competitive natural BB remains limited. Subsequently, evidence of the physiological and psychological consequences of these practices has been largely examined in case studies. Given the body composition outcomes achieved by this population, extending the current body of topic-related literature focussed on this population is warranted, and may identify hitherto undocumented practices which warrant further investigation. Furthermore, identification of such practices may offer opportunities to extend these findings to both athletic and non-athletic populations aiming to reduce fat mass whilst maintaining muscle mass.

CHAPTER 3.

Muscle Dysmorphia Symptomatology and Associated Psychological Features in Bodybuilders and Non-Bodybuilder Resistance Trainers: A Systematic Review and Meta-analysis

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ABSTRACT

Background: Associated with a self-perceived lack of size and muscularity, muscle dysmorphia (MD) is characterised by a preoccupation with and pursuit of a hyper-mesomorphic body. MD symptoms may hypothetically be more prevalent in bodybuilders (BB) than non-bodybuilder resistance trainers (NBBRT).

Objective: Compare MD symptomatology in BB to NBBRT, and identify psychological and other characteristics associated with MD in these groups.

Methods: Relevant databases were searched from earliest record to February 2015 for studies examining MD symptoms in BB and/or NBBRT. Included studies needed to assess MD using a psychometrically validated assessment tool. Study quality was evaluated using an adapted version of the validated Downs & Black tool. Between-group standardized mean difference [effect sizes (ES)] and 95% confidence intervals (CI) for each MD subscale were calculated. Meta-analysis was performed when five or more studies used the same MD tool. Data describing psychological or other characteristics associated with MD were also extracted.

Results: Of the 2135 studies initially identified, 31, analysing data on 5880 participants (BB: $n = 1895$, NBBRT: $n = 3523$, controls: $n = 462$) were eligible for inclusion, though study quality was generally poor-moderate (range 7-19/22). Most participants were male (90%). Eight different MD assessment tools were used. Meta-analysis for five studies all using the Muscle Dysmorphia Inventory (MDI) revealed there was a medium to large pooled ES for greater MD symptomatology in BB than NBBRT on all MDI subscales (ES: 0.53 to 1.12; $p \leq 0.01$). Competitive BB scored higher than non-competitive BB (ES = 1.21, 95% CI: 0.82-1.60; $p < 0.001$). MD symptoms were associated with anxiety (r: 0.32 to 0.42; $p \leq 0.01$), social physique anxiety (r: 0.26 to 0.75; $p < 0.01$), depression (r: 0.23 to 0.53; $p \leq 0.01$), neuroticism (r: 0.38; $p < 0.001$) and perfectionism (r: 0.35; $p < 0.05$) and inversely associated with self-concept (r: -0.32 to -0.36; $p < 0.01$) and self-esteem (r: -0.42 to -0.47; $p < 0.01$).

Conclusions: There was greater MD symptomatology in BB than NBBRT. Anxiety and social physique anxiety, depression, neuroticism and perfectionism were positively associated with MD, while self-concept and self-esteem were negatively associated. It remains unclear whether these characteristics are exacerbated by bodybuilding, or whether individuals with these characteristics are attracted to the bodybuilding context.

INTRODUCTION

Societal expectations of the ideal physique for men and women have evolved over time [57,58]. A large body of research has identified the ideal male physique as mesomorphic, strong, athletic and lean [59-61]. For females there is an increasing acceptability of a lean and muscular physique, progressing from the previously idealized thin and toned body [59,62]. The rewards for attaining this ideal physique, and the pressure associated with achieving it, drive attempts to alter body size and shape, and particularly for males, increase muscle size and strength [59,62]. This is achieved through dietary modifications as well as exercise, especially resistance training. The popularity of muscularity enhancing pursuits has steadily increased. Evidence suggests that resistance training is one of the most common worldwide fitness trends [63], the use of muscle-building dietary supplements such as protein and creatine is common [64,65], and the prevalence of anabolic-androgenic steroid (AAS) use in adolescents and adults is predicted to be high [66,67].

Muscle dysmorphia (MD) is characterized by a pathological preoccupation with, and pursuit of, a lean, hyper-muscular body, coupled with the belief that one is insufficiently muscular [43]. Individuals engage in obsessive behaviours regarding nutrition, exercise, and often AAS use in order to achieve this mesomorphic body [46,47]. Whilst muscle dissatisfaction is increasingly common amongst males [68,69], the distinguishing characteristics differentiating MD from a non-pathological desire to increase muscle mass are the overvaluation of the ideal body shape, and a disproportionate influence of one’s body in determining self-worth [44]. In conjunction with this is a disturbed body-image perception, whereby individuals have a core belief that they are insufficiently muscular, when in fact they are large and strong [14]. Compensatory efforts to allay the anxiety associated with this belief include engagement in rigid, pathological eating and exercise practices [14,15,45] and often also excessive use of dietary supplements and AAS [46,47]. Mild deviation from these regimes results in marked distress [14]. The body dissatisfaction is associated with other behavioural symptoms, including declining social, occupational or recreational activities in order to maintain workout and diet schedules, and avoiding situations where the body is exposed, such as the locker room or beach [14].

A similarly fastidious pursuit of hyper-muscularity is often seen amongst bodybuilders (BB), who commit to a rigorous diet and training regimen with the aim to achieve a highly muscular, lean, symmetrical and well-proportioned physique [10]. In competitive bodybuilding, participants pose before a panel of judges, who score each entrant on the basis of muscular size, definition, development and symmetry [10]. Individuals may rely heavily on the use of supplements to attain the most muscular and sculpted physique, and a subgroup of BB use appearance and performance enhancing drugs designed to aid in the accumulation of muscle mass, including AAS [18,70,71]. Thus, it is logical to suggest that bodybuilding as a context and process may appeal to those with MD symptoms, either seeking body image satisfaction or removal of existing symptoms; but likewise, the performance and social context itself could also increase the manifestation of MD symptomatology and associated behaviours.

In delineating between the pathological pursuit of muscularity, and a sport that covets the cultivation of muscle mass, the history of MD has been intertwined with bodybuilding since its recognition in the early 1990s. The first reported cases of MD were in a group of BB who described beliefs of appearing small and weak despite the reality of them being physically large and muscular [19]. The authors identified these BB as suffering from a ‘reverse anorexia’, due to the similar but reverse body-related concerns and behaviours as those suffering from anorexia nervosa. Subsequent research led to the renaming of the condition as MD based on the thesis that compulsive exercise was more central in MD than pathological eating [14], with tentative diagnostic criteria formalizing the nosological integrity of this cluster of symptoms. Since then, the disorder has been often measured in BB, as well as power lifters [15], recreational weight trainers [48], college footballers [51], and non-trained individuals [50].

Given the increasing popularity of resistance training to improve muscularity, both within the general community and in athletes, and the well-documented benefits of increased muscle mass and reduced fat mass for chronic disease prevention [8], a critical endeavour lies in accurately delineating between healthful muscularity-enhancing pursuits versus pathological endeavours. While several reviews of MD have been published spanning both its nosological status [45,72] and aetiological underpinning [44,73], few have explicitly addressed the distinction between a pathological versus non-pathological pursuit of hyper-muscularity, and many have conflated the terms bodybuilding and MD. An inadequate distinction between such pursuits is of great clinical and empirical significance, as the pathologizing of normative muscularity enhancing pursuits likely augments the existing stigma related to muscularity-related body image concerns [74], in addition to confounding treatment studies. Therefore, the primary aim of this study was to conduct a systematic review with meta-analysis to compare MD symptomatology between BB and non-bodybuilder resistance trainers (NBBRT). Such a comparison will determine if engagement in bodybuilding results in more severe MD symptomatology. A secondary aim was to identify psychological features and other characteristics associated with MD in BB and NBBRT.

METHODS

Design

A systematic literature search was conducted by one researcher (LM) to identify studies examining MD in BB and resistance trained individuals. Databases searched from earliest record until February 2015 were: Medline (Ovid), PsycINFO(Ovid), CINAHL (EBSCO), Proquest 5000 (via Proquest central), Scopus, PubMed, SPORTDiscus (EBSCO), and Web of Science.

The search strategy combined the following keywords (Appendix A1): (muscle dysmorphia, bigorexia, reverse anorexia, Adonis complex, manorexia, male eating disorder) and (bodybuilding, body building, bodybuilder, body builder, strength training, weight training, resistance training, progressive training, progressive resistance, weight lifting, athlete). Reference lists of all retrieved papers were manually searched for potentially additional eligible papers. Following the search a PRISMA [75] informed systematic review process was completed.

Inclusion and Exclusion criteria

Included studies were required to describe MD in participants defined by study authors as BB or NBBRT. Studies could be descriptive, cross-sectional, case study or longitudinal design. Baseline measurement of MD from randomised controlled trials or intervention studies was also eligible for inclusion. Studies were included if they measured MD using a psychometrically validated scale of MD symptomatology. Studies were considered eligible if participants were in any phase of training, competition preparation or competition recovery. Due to the large number of magazine and newspaper articles, television and radio transcripts, the search was limited to full-text peer-reviewed journal manuscripts. Theses were excluded. Manuscripts from all languages were included.

After eliminating duplicates, the search results were screened by one reviewer (LM) against the eligibility criteria. Those references that could not be eliminated by title and abstract were retrieved and independently reviewed for inclusion.

Data Extraction and Conversions

Data relating to the manuscript, namely author(s), date of publication, and country where the study was conducted were recorded. The institution country of the first author was used as the country if this was not described in the text. Data extracted from each paper included participant characteristics (age, sex, hours of training per week, years of training, competition calibre, weight, height, body composition and ethnicity), MD assessment tools utilized and scores, data on assessed psychological features (perfectionism, anxiety, self-esteem, neuroticism, self-concept, depression, extraversion) including the psychological assessment tool utilized and correlation (Pearson's *r*) with MD score. Likewise, any information related to AAS and other performance enhancing substance use, and comorbid diagnoses were extracted. All data were independently extracted from each paper by two of four researchers (LM, DH, SC, LC) with disagreements resolved by discussion with a third researcher (HO). In cases where journal articles contained insufficient information, attempts were made to contact authors to obtain missing details. In some studies, data for MD scores were not presented in numerical form, but rather in graphical format. In this instance, graphs were enlarged, and data obtained using a ruler, in duplicate. Anthropometrical parameters reported in imperial units (e.g., pounds, inches) were converted to kg and cm (1 kg = 2.2 pounds; 1 cm = 0.3937 inches). Body mass index (BMI) was calculated (weight/height^2) from the mean height (m) and body mass (kg). Extracted data were presented as mean and standard deviation (SD) when SD was reported. Weighted means were calculated for age, anthropometric variables, and training history.

Assessment of methodological quality

The methodological quality of the 31 papers which met inclusion criteria were assessed by two of three researchers (LM, JG, LC) using a modified version of an assessment scale devised by Downs and Black [76]. One researcher (LM) assessed all papers. Two others (JG, LC) shared the parallel assessment of the 31 papers. In using the scale, 16 of the 27 items of the original checklist were retained. Items 4, 8, 9, 13, 14, 15, 17, 19, 23, 24 and 26 were excluded based on their lack of relevance to the included studies. These items were excluded as they related to interventions (items 4, 8, 13, 14, 17, 19, 23, 24), follow-up assessments (9, 26) and blinding of subjects and measurers (14, 15). An additional seven items were included from a secondary checklist [77] as these items were relevant to the assessment of the literature included in this study. The seven items were:

- "If cohort or cross-sectional study, were groups comparable on important confounding factors and/or were pre-existing differences accounted for by using appropriate adjustments in statistical analysis?"
- "Were psychological measures appropriate to the question and outcome of concern?" (Modified from "nutrition measures")
- "Were the observations and measurements based on standard, valid and reliable data collection instruments/procedures?"
- "Was clinical significance as well as statistical significance reported?"
- "Is there a discussion of findings?"
- "Are study biases and study limitations identified and discussed?"
- "Were the sources of funding and investigators' affiliations described?"

Each reviewer checked for internal (intra-rater) validity across items for each paper. Differences in scores between researchers were discussed, with disagreements resolved via discussion with a third researcher (HO) for consensus.

Analyses

In order to descriptively compare MD symptomatology between BB and NBBRT, and to identify characteristics associated with MD, the between-group standardized mean difference, or effect size (ES), and 95% confidence interval (CI) were calculated for each subscale of MD tools used in studies which provided sufficient data. Extracted data (mean, standard deviation and sample size) were transferred to Comprehensive Meta-Analysis Version 2 software (Biostat, 2005, Englewood, USA) for calculation of ES and 95% CI. In studies where sufficient data (i.e. mean, standard deviation or sample size) were not present, no data analysis was conducted, instead raw data were extracted and tabulated. Extracted correlation data between MD score and psychological features were used to identify associations between MD symptomatology and psychological features. These correlations were not analysed, instead raw data (Pearson's *r*) were extracted and tabulated.

Meta-analyses

In order to quantitatively compare MD symptomatology between BB and NBBRT, meta-analyses of mean differences of Muscle Dysmorphia Inventory (MDI) subscales between BB and NBBRT were performed. Meta-analyses of mean differences of other scales were not performed due to an inadequate number of studies using each of these scales to compare BB with NBBRT to warrant meta-analysis. Comprehensive Meta-Analysis was used for all pairwise comparisons in the quantitative analysis. Standardized mean differences (ES), standard error, variance, and 95% CI were calculated. An invariance random effects model was applied, assuming that studies drew on divergent populations and contexts and potentially included different research designs. Forest plots were generated to display ES and 95% CI results of each study, and the pooled estimate. The pooled estimate was described based on Cohen's suggestions [78], whereby a small ES was > 0.2, a medium ES was > 0.5, and a large ES was > 0.8. A positive ES indicated an effect favouring BB, whereas a negative ES indicated an effect favouring NBBRT. The Q statistic (with df and p value) provided a test of the null hypothesis that all studies shared a common effect size. If all studies shared a similar effect size, the *Q* value would be approximately equal to the degrees of freedom. The I^2 statistic identified the proportion of the observed variance reflecting differences in true effect sizes as opposed to sampling error. Moderate to high values (i.e., ≥ 0.50) were considered as demarcating the likelihood of heterogeneity.

To maintain independence, only one BB group and one NBBRT group were included in the meta-analysis from each paper. Where more than one group was present in a study: 1) competitive BB were selected; 2) non-AAS users were selected; 3) NBBRT for a sport were not selected.

RESULTS

Identification and Selection of Studies

The original search netted 2135 potential articles. An additional article was included after hand searching the reference list of all retrieved papers. After the removal of duplicates (*n* = 624), a further 1431 were excluded after screening title and abstract. The full text of the remaining 81 articles was retrieved. Of these, 50 were excluded due to not meeting the eligibility criteria, resulting in 31 eligible manuscripts. A summary of the systematic PRISMA process is shown in Figure 3.1.

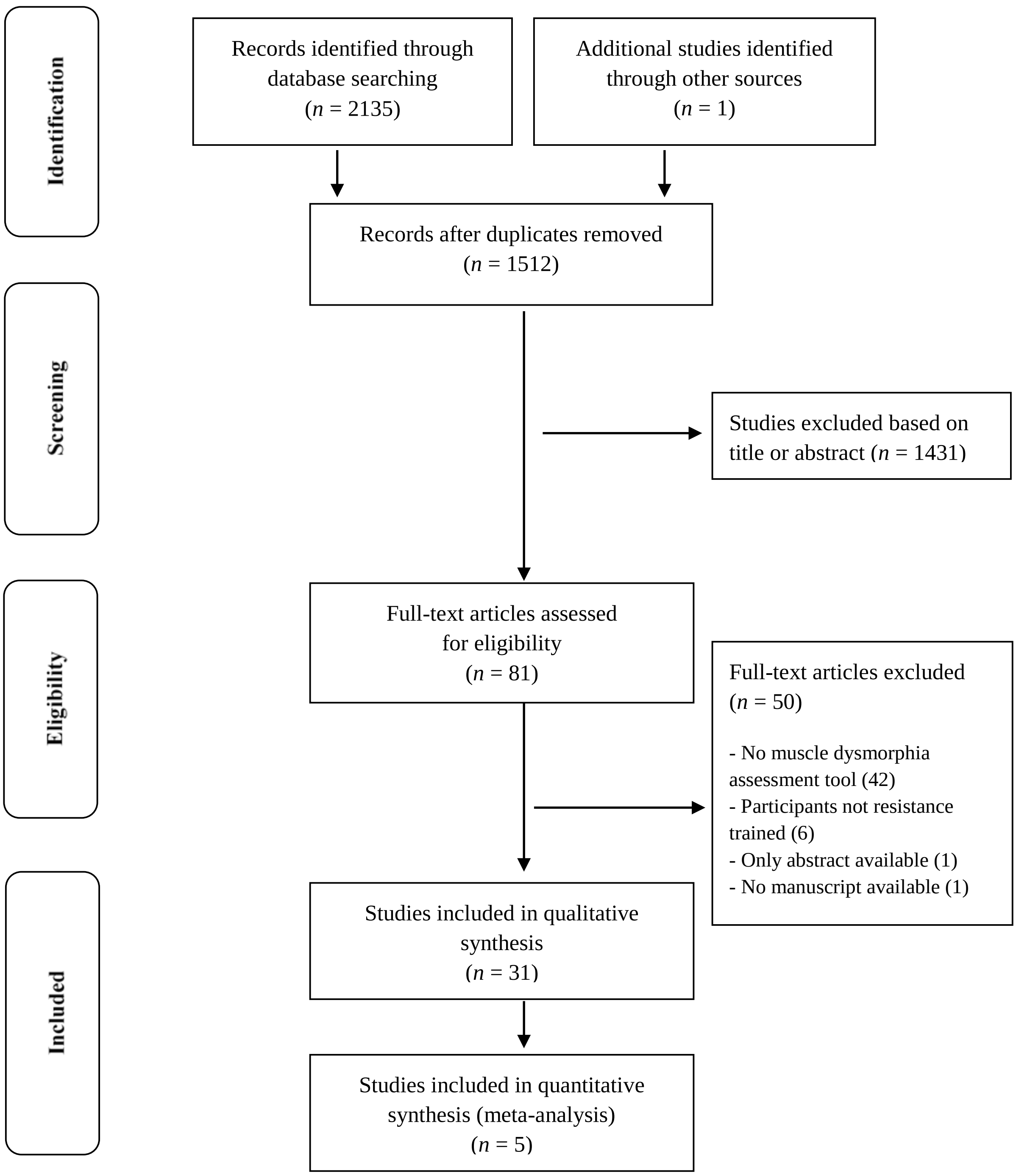

Figure 3.1. Flowchart showing the process for inclusion of studies

Evaluation of Methodological Quality

Methodological quality was evaluated in 29 of the 31 studies. Two studies [79,80] could not be rated as an adequate English translation of all text was not available. The mean quality rating score was 12.2 (SD ± 2.5) from a possible 22 (Appendix A). All studies described the main outcomes to be measured, described the main findings in the results, and discussed the findings. All but one study specified their hypotheses [47], and all but one study used appropriate statistical tests [81]. The lowest scores were for items "Were the subjects asked to participate in the study representative of the entire population?" (mean score 0.03 ± 0.19), "Were those subjects who were prepared to participate representative of the entire population from which they were recruited?" (mean score 0.07 ± 0.26), and "Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?" (mean score 0.07 ± 0.26).

Demographic characteristics, Competition Phase/Calibre, and Drug Use

Participant demographic characteristics are outlined in Tables 3.1 and 3.2 for studies including BB and NBBRT, respectively. The 31 studies described a total of 5880 participants (BB *n* = 1895, NBBRT *n* = 3523, non-training controls *n* = 462). The weighted mean age of all participants was 28 ± 7.6 years. The male and female BB were 30.9 ± 8.6 and 34.2 ± 8.7 years, respectively. The male and female NBBRT were 27.3 ± 7.4 and 22.2 ± 5.5 years, respectively. The male and female non-training controls were 23.7 ± 4.4 and 27.3 ± 6.2 years, respectively. Of the 31 studies, 21 described men, one described women, and the remaining nine studies described both men and women. A large number of studies were conducted in Europe (*n* = 14) and the US (*n* = 12), while two were from Brazil, and one each from Australia, Chile and Korea. The BB had trained for a mean of 10.8 years (range 4-16) and the NBBRT five years (range 2.5-9). Use of anabolic agents was reported in seven of the 31 studies [17,47,49,51,55,82,83], with two of these studies also reporting or implying no steroid use via participants competing in drug tested competition, leaving the drug-taking status of the remaining 24 studies unknown.

Eight of 31 studies reported participant calibre [15,48,50,51,55,82,84,85]. Participants were identified as national [15,85], professional [51], expert [48], novice [48], competitive or non-competitive [50,55,82,84] (see Tables 3.1 and 3.2). One study reported the competition phase of participants [15] with the remaining 30 studies not identifying the phase of training or competition cycle.

Anthropometric and Body Composition Characteristics

The weighted mean height of male and female BB was 175.4 cm (range 154.9-180.6) and 156.2 cm (range 150-168.3), respectively, for male and female NBBRT was 178.6 cm (range 172.7-185.6) and 165.6 cm (range 153-168.2), respectively, and for the male non-training controls was 181.4cm (range 180.5-181.6). Height was not reported for female non-training controls in any of the studies. The weighted mean body mass, BMI and percent fat of male BB was 90.9 kg (range 81.8-96.1), 29.7 $kg{\cdot}m^{-2}$ (range 24.6-37.5), and 9.8% (range 9.4-10.3). In male NBBRT, these parameters were 86.9 kg (range 75.9-103.2), 27.2 $kg{\cdot}m^{-2}$ (range 25.1-30.0), and 12.9% (range 10.3-18.4). In male non-training controls, weighted mean body mass and BMI were 76.5 kg (range 75.6-80), 23.5 $kg{\cdot}m^{-2}$ (range 22.9-25). The weighted mean body mass and BMI for female BB were 65.5 kg (range 63.6-69) and 27 $kg{\cdot}m^{-2}$ (range 24.4-28.3). For female NBBRT, these parameters were 64.2 kg (range 61.9-70.9), and 23.6 $kg{\cdot}m^{-2}$ (range 22-28.4), respectively. For female non-training controls weighted mean BMI was 22.7 $kg{\cdot}m^{-2}$ (range 18.7-26.5). Body fat was not reported for females or non-training controls in any of the studies, nor was body mass for female non-training controls.

Table 3.1. Participant characteristics of bodybuilders

Reference	Group	n	Sex	Age, y	Country	Weight, kg	Height, cm	BMI, kg/m^2	%Fat	Training, y	Calibre	Drug use
Babusa and Tury [55]	BB	60	M	27.7±7.53	Hungary	88.5±14.73	180.6±7.23	27.13			NC	18.3% yes
	Control	60	M	27.8 ±7.45		80±12.47	180.5±8.62	24.55			NS	
Boyda and Shevlin [89]	BB	51	M	31.33±8.06 [18-55]	UK						NS	
Castro-Lopez et al. [79]	BB	154	M, F	24.97±6.9 [16-49]	Spain						NS	
Gonzalez-Marti et al. [90]	BB and weightlifters	734	M, F	30.92±9.41	Spain	73.73±12.07	171±8.47	25.2			NS	
Lopez-Barajas et al. [91]	BB	154	M, F	24.97±6.9 [16-49]	Spain						NS	

Wolke and Sapouna [92]	BB	200	M	29.8±9.1 [16-62]	UK	92.9±15.13	177.83±7.55	29.28±4.49			NS	
Baghurst et al. [51]	Non-natural BB	47	M		US	96.13±13.44	167.41±35.36	34.33	10.28 ±2.36	16.02±10.26	P	Yes
	Natural BB	65	M	32.22±11.12		87.56±11.33	173.86±20.75	28.97	9.43±3.11	12.97.76	80.3% P	No
	Weight train for physique	115	M	29.78±10.22		88.7±15.58	177.62±12.93	28.12	12.83±7.04	8.51±8.16	NS	
	Footballers	66	M	20.5±4.41		103.15±18.57	185.55±8.31	29.96	10.31±4.38	5.68±2.44	NCAA collegiate	
Cella et al. [86]	BB	119	M	30.63±7.85	Italy						NS	
	Non-BB	98	M	30.86±8.669							NS	
Davies and Smith [82]	Former AAS-users	30	M	30[18-48]	UK						NC	No
	AAS users	30	M	30[18-70]							NC	Yes
Hale et al. [48]	Expert BB	26	F	18-48	US					7.95±5.65	E	

	Novice BB	29	F	18-48					7.48±5.23	NV
	Fitness lifters	19	F	18-48					3.96±3.16	NS
Lantz et al. [15]	BB	100	M, F	30.99±7.22	US				12.75±4.49	N
	Powerlifters	68	M, F	31.68±6.62					15.53±7.74	N
Santarnecchi and Dettore [50]	Competitive BB	60	M	33±7 [23-41]	Italy			27.93		C
	Non-competitive BB	60	M	32±10 [23-36]				24.6		NC
	Control (non-training)	60	M	33±8± [24-37]				25.02		NS
Skemp et al. [84]	Appearance enhancement	51	M, F	35.3	US	77	159.77	30.16		C, NC
	Performance enhancement	82	M, F	27.4		86.05	172.72	28.84		C, NC

Soler et al. [85]	BB	25	M	30.8±5.45	Brazil	81.8±17.24	174±7.0	27.76±5.03	11.12±6.87	N
	Gymgoers	151	M	27.66±6.54		82.87±13.11	177±7.0	26.72±4.24	6.25±5.62	NS

Data are presented as mean ± SD [range]. BMI, body mass index; BB, bodybuilder; M, male; F, female; C, competitive; NC, non-competitive; E, expert; NV, novice; P, professional; NS, not stated; N, national; NCAA, National Collegiate Athletic Association; AAS, anabolic-androgenic steroids

Table 3.2. Participant characteristics of non-bodybuilder resistance trainers

Reference	Group	n	Sex	Age, y	Country	Weight, kg	Height, cm	BMI, kg/m^2	%Fat	Training, y	Drug use
Babusa et al. [49]	Weightlifters	289	M	28±7.43	Hungary	87.8±14.76	179.6±6.06	27.2±4.13		6.1±6.08	10% yes
	Controls	240	M	20.3±2.78		75.6±14.7	181.6±7.48	22.9±3.98			
Cafri et al. [102]	Weightlifters with MD	23	M		US						
	Weightlifters without MD	28	M								
Hildebrandt et al. [93]	Weightlifters	237	M	32.64±12.37	US			26.7±4.35	12.52±5.6	8.92±7.94	
Kanayama et al. [83]	AAS users	48	M	29.3±6.5	US						Yes

	Non-users	41	M	30.1±10.5							No
Kim et al. [80]	Resistance trained	429	M		Korea						
Kuennen and Waldrom [94]	Resistance trained	49	M	28.27±8.35	US	93.71±14.07	179±0.7	29.25	18.36±6.14		
Maida and Armstrong [95]	Resistance trained	106	M	18-45	US						
Segura-Garcia et al. [88]	Male gain	52	M	27.2±6.8	Italy			23.6±2.8			
	Male lose	34	M	28.4±7				26.5±2.2			
	Female lose	48	F	28.6±5.8				21.6±2.9			
	Eating disorder	20	F	22.1±5.6				18.7±2.9			
Thomas et al. [17]	Resistance trained	146	M	22.8±5.0	UK	82±11.1	180±7.0	25.1±3.0		2.9±1.9	

De Lima et al. [98]	Resistance trained	23	M	24±3.8	Brazil	75.9±9.4					
Giardino and Procidano [81]	Male Mexican	35	M	23.34±4.26	Mexico						
	Female Mexican	11	F	22.18±2.4	Mexico						
	Male US	43	M	20.47±2.26	US						
	Female US	24	F	20.17±1.37	US						
Nieuwoudt et al. [99]	Resistance trained	648	M	29.5±10.1	Australia						
Olivardia et al. [47]	Weightlifters with MD	24	M	25.4±3.7	US	89.63±16.36	175.51±6.86	28.94	13.1±5.4		46% yes
	Weightlifters without MD	30	M	25.4±3.2	US	84.54±16.27	177.29±6.1	26.98	14.1±6		7% yes
Robert et al. [97]	Male	55	M	24.06±7.96	US	83.45±14.72	181.23±6.81	25.32±3.73		3.85±1.22	
	Female	59	F	21.88±5.34		61.93±7.54	168.22±7.1	22.02±2.67		3.49±1.28	

Skemp et al. [84]	Male	79	M	31.7	US	93.0	175.6	30.16			
	Female	54	F	29.3		67.23	158.28	26.84			
Thomas et al. [96]	Resistance trained	30	M	20.93±2.6	UK	86.87±10.59	176.0±1.0	28.04		3.57±2.53	13% yes
Tod and Edwards [100]	Resistance trained	294	M	20.5±3.1	UK					2.47±2.4	
Valdes et al. [101]	Male	112	M	18-25	Chile						
	Female	88	F	18-25	Chile						

Data are presented as mean ± SD [range]. BMI, body mass index; M, male; F, female; MD, muscle dysmorphia; AAS, anabolic-androgenic steroids

Muscle Dysmorphia Assessment Tools

In the 31 studies, eight different tools were used to assess MD. The most commonly used tools were the MDI (n = 11) and the Muscle Appearance Satisfaction Scale (MASS) (n = 11). Other tools used were the Muscle Dysmorphic Disorder Inventory (MDDI) (n = 6), the Adonis Complex Questionnaire (n = 3), the Bodybuilder Image Grid (BIG) (n = 2), the Muscle Dysmorphia Questionnaire (n = 2), the Muscle Dysmorphia Symptom Questionnaire (MDSQ) (n = 2) and the Muscle Appearance Satisfaction Scale-6 (n = 1).

Muscle Dysmorphia

The results of MD symptom severity assessment are presented in Tables 3.3-3.5. Computations of standardized mean difference, ES and 95% CI are presented in Tables 6-13.

Do bodybuilders display more muscle dysmorphia symptoms than non-bodybuilders?

Eight of 31 studies compared prevalence of MD symptoms in BB and non-BB, each of which provided sufficient data to enable calculation of ES [15,48,50,51,55,84-86]. The BB groups comprised of competitive, non-competitive, steroid using, non-steroid using, expert, novice, male and female bodybuilders. Non-bodybuilders ranged from non-training controls and recreational fitness lifters, to competitive powerlifters and collegiate footballers. Of the eight studies, four tools were used to measure MD symptoms: MDI (n = 4), MDDI (n = 1), MASS (n = 1), MDDI and BIG (n = 1), and MDI and MASS (n = 1).

The MD subscale scores of the BB are summarised in Table 3.3. Five studies assessed MD using the MDI in BB and NBBRT [15,48,51,84,86]. In the case of the dietary behaviour subscale, all five studies showed a significant ES of BB on subscale score (ES range: 0.66 to 1.96, $p < 0.001$) [15,48,51,84,86]. Similarly, for the supplement use subscale all five studies showed a positive ES of BB (ES range: 0.1 to 2.35), four of which were significant ($p \leq$

0.002) [48,51,84,86]. Four of five studies showed a positive ES of BB for the pharmacological use subscale (ES range: -0.1 to 0.99), three of which were significant ($p < 0.001$) [15,84,86]. On the exercise dependence subscale, three of the four studies showed a significant positive ES of BB (ES range: 0.03 to 2.15, $p \leq 0.006$) [48,84,86]. For the size/symmetry subscale, all five studies showed a positive ES of BB (ES range: 0.09 to 1.67), of which four were significant ($p \leq 0.04$) [15,48,84,86]. The final subscale, physique protection, also had an ES favouring BB in all five studies (ES range: 0.07 to 1.13), with a significant difference in four studies ($p \leq 0.021$) [15,48,84,86] (Table 3.6).

Two studies assessed MD using the MDDI in BB [50,85] (Table 3.7). One study used NBBRT as a comparison group [85], while the second study used non-training controls as a comparison group [50]. Results for these studies varied. BB showed a positive ES on MDDI total in both studies (ES range: 0.03 to 3.62), but only one of these was significant ($p < 0.001$) [50]. In the case of the drive for size subscale, one study showed a significant positive ES of BB (ES range: -0.05 to 2.47, $p < 0.001$) [50]. The ES for the appearance intolerance subscale significantly favoured BB in one study (ES: - 0.07 to 1.2, $p < 0.001$) [50]. Both studies showed an ES favouring BB on the functional impairment subscale (ES range: 0.26 to 2.945), one of which was significant ($p < 0.001$) [50].

Table 3.3. Muscle dysmorphia assessment results of bodybuilders

Reference	Group	n	Tool	Subscale	Results	Main findings
Baghurst et al. [51]	Non-natural BB	47	MDI	Dietary behaviour	23.04±3.37	Non-natural BB significantly higher (p<0.05) than natural BB on pharmacological subscale, significantly higher (p<0.05) than weight training for physique on all subscales except physique protection and size/symmetry, significantly higher (p<0.05) than football on all subscales except physique protection
				Supplement use	17.85±3.83	
				Pharmacological use	6.29±2.57	
				Size/symmetry	21.15±4.92	
				Physique protection	14.38±5.53	
	Natural BB	65	MDI	Dietary behaviour	23.35±4.73	Natural BB significantly higher (p<0.05) than weight training for physique on dietary behaviour, supplement use. Significantly higher (p<0.05) than football for all subscales except physique protection and pharmacological use
				Supplement use	16.63±3.99	
				Pharmacological use	3.65±1.38	
				Size/symmetry	20.02±5.14	
				Physique protection	13.46±4.82	
	Weight training for physique (NBBRT)	115	MDI	Dietary behaviour	20.17±4.89	Significantly higher (p<0.05) than football for dietary behaviour, size/symmetry
				Supplement use	13.82±4.96	
				Pharmacological use	3.79±1.47	
				Size/symmetry	19.52±5.67	
				Physique protection	13.08±5.79±	

	Football	66	MDI	Dietary behaviour	16.56±4.85	Significantly higher ($p<0.05$) than natural BB for
				Supplement use	12.3±4.6	dietary behaviour, size/symmetry
				Pharmacological use	5.62±4.03	
				Size/symmetry	16.83±4.8	
				Physique protection	17.38±5.62	
Cella et al.	BB	119	MDI	Dietary behaviour	22.45±5.52	n=4 (3.4%) met MD diagnostic criteria
[86]			MASS	Supplement use	16.49±5.97	BB significantly higher ($p\leq0.003$) scores on all MDI
				Pharmacological use	4.71±3.25	subscales, significantly higher ($p<0.001$) scores on all
				Exercise dependence	18.61±4.27	MASS subscales except muscle satisfaction
				Size/symmetry	17.59±6.41	
				Physique protection	14.88±8.47	
				MASS total	55.72±16.93	
				Bodybuilding dependence	14.41±5.64	
				Muscle checking	10.21±5.08	
				Substance use	9.73±4.55	
				Injury	9.09±3.64	
				Muscle satisfaction	11.25±3.26	
	NBBRT	98	MDI	Dietary behaviour	10.98±8.86	
			MASS	Supplement use	6.6±3.51	

		Pharmacological use	3.12±0.52	
		Exercise dependence	9.96±5.17	
		Size/symmetry	8.86±3.65	
		Physique protection	7.5±2.63	
		MASS total	33.02±9.4	
		Bodybuilding dependence	8.02±3.54	
		Muscle checking	5.31±2.3	
		Substance use	5.07±2.16	
		Injury	5.11±3.13	
		Muscle satisfaction	9.55±3.13	
BB, AAS users	MDI	Dietary behaviour	24.26	AAS users significantly higher ($p<0.05$) on all MDI subscales except exercise dependence, significantly higher ($p\leq0.003$) on all MASS subscales except muscle satisfaction
	MASS	Supplement use	19.0	
		Exercise dependence	19.21	
		Size/symmetry	21.44	
		Physique protection	19.74	
		Bodybuilding dependence	17.47	
		Muscle checking	12.3	
		Substance use	12.79	
		Injury	10.88	

				Muscle satisfaction	11.02	
	BB, AAS non-users		MDI MASS	Dietary behaviour	21.43	
				Supplement use	15.07	
				Exercise dependence	18.28	
				Size/symmetry	15.41	
				Physique protection	12.13	
				Bodybuilding dependence	12.68	
				Muscle checking	9.03	
				Substance use	8.0	
				Injury	8.08	
				Muscle satisfaction	11.38	
Hale et al. [48]	Expert BB	26	MDI	Dietary behaviour	23.92±3.78	Expert and novice BB significantly higher ($p<0.05$) than fitness lifters on all subscales except pharmacological use and physique protection
				Supplement use	18.42±4.82	
				Pharmacological use	4.27±1.71	
				Exercise dependence	19.54±3.64	No difference between expert and novice BB
				Size/symmetry	17.62±4.34	
				Physique protection	13.04±3.84	
	Novice BB	29	MDI	Dietary behaviour	21.44±5.32	
				Supplement use	14.1±6.21	

				Pharmacological use	4.34±2.58	
				Exercise dependence	16.93±3.66	
				Size/symmetry	16.17±6.69	
				Physique protection	13.97±7.24	
	Fitness lifters (NBBRT)	19	MDI	Dietary behaviour	13.89±6.39	
				Supplement use	7.86±3.77	
				Pharmacological use	3.63±1.64	
				Exercise dependence	11.31±3.93	
				Size/symmetry	10.26±4.29	
				Physique protection	10.53±2.98	
Lantz et al. [15]	BB	100	MDI	Dietary behaviour	32.9±8.15	BB significantly higher ($p<0.001$) than powerlifters on all subscales except supplement use and exercise dependence
				Supplement use	15.59±5.15	
				Pharmacological use	12.76±4.56	
				Exercise dependence	20.9±3.44	
				Size/symmetry	18.9±5.17	
				Physique protection	7.88±2.95	
	Powerlifters (NBBRT)	68	MDI	Dietary behaviour	26.16±7.89	
				Supplement use	15.15±6.62	
				Pharmacological use	9.89±3.34	

				Exercise dependence	20.78±4.17	
				Size/symmetry	16.24±5.44	
				Physique protection	6.46±2.63	
Skemp et al. [84]	Appearance enhancement athletes (BB)	51	MDI	Dietary behaviour	20±6	Appearance enhancement significantly higher ($p<0.01$) than performance enhancement on all MDI subscales
				Supplement use	13±6	
				Pharmacological use	4±1	
				Exercise dependence	17±4	
				Size/symmetry	15±6	
				Pharmacology use	10±4	
	Performance enhancement athletes (NBBRT)	82	MDI	Dietary behaviour	15±6	
				Supplement use	10±5	
				Pharmacological use	3±1	
				Exercise dependence	15±4	
				Size/symmetry	13±5	
				Physique protection	8±3	
	Male weight trainers (NBBRT)	79	MDI	Dietary behaviour	17±6	Males significantly higher ($p<0.05$) than females on supplement use, physique protection, size/symmetry
				Supplement use	12±5	
				Pharmacological use	3±1	
				Exercise dependence	16±4	

				Size/symmetry	16±6	
				Physique protection	10±4	
	Female weight trainers (NBBRT)	54	MDI	Dietary behaviour	17±7	
				Supplement use	10±6	
				Pharmacological use	4±1	
				Exercise dependence	16±4	
				Size/symmetry	11±4	
				Physique protection	9±3	
Santarnecchi et al. [50]	Competitive BB	60	MDDI BIG	MDDI total	38.5±7.97	Competitive BB significantly higher (p<0.01) than non-competitive and non-training controls on MDDI total and all subscales, current muscle mass, ideal muscle mass, most attractive muscle mass indices of BIG
				Drive for size	15.45±4.78	
				Appearance intolerance	10.32±3.9	
				Functional impairment	11.87±3.58	
				Current body type – fat	27.33±17.84	Significantly lower (p<0.001) than non-competitive BB and non-training individuals on all fat indices of BIG
				Current body type – muscle mass	64.33±12.12	
				Ideal body type – fat	14.33±9.63	
				Ideal body type – muscle mass	75.17±16.0	
					15.33±9.47	

			Most attractive body type – fat	69.0±16.12	
			Most attractive body type – muscle mass	19.0±11.75	
			Most attractive to women – fat	51.67±13.92	
			Most attractive to women – muscle mass		
Non-competitive BB	60	MDDI BIG	MDDI total	29.6±6.56	Non-competitive BB significantly higher ($p<0.01$) than non-training individuals on MDDI total and all subscales, and current, ideal and most attractive muscle mass BIG indices
			Drive for size	10.0±4.0	
			Appearance intolerance	14.63±3.95	
			Functional impairment	6.32±4.17	
			Current body type – fat	41.67±18.33	Significantly lower ($p<0.05$) than non-training individuals on current and ideal fat indices
			Current body type – muscle mass	46.83±18.55	
			Ideal body type – fat	30.5±17.02	
			Ideal body type – muscle mass	53.17±9.83	
				32.5±17.31	

			Most attractive body type – fat	53.17±9.11
			Most attractive body type – muscle mass	31.5±17.45
			Most attractive to women – fat	47.33±14.36
			Most attractive to women – muscle mass	
Non-training individuals	60	MDDI BIG	MDDI total	16.1±3.45
			Drive for size	5.83±2.66
			Appearance intolerance	6.23±2.79
			Functional impairment	3.57±1.68
			Current body type – fat	50.67±18.4
			Current body type – muscle mass	29.33±15.17
			Ideal body type – fat	37.33±16.04
			Ideal body type – muscle mass	42.0±16.95
				38.0±18.48

				Most attractive body type – fat	45.33±15.35	
				Most attractive body type – muscle mass	32.67±18.58	
				Most attractive to women – fat	50.67±14.25	
				Most attractive to women – muscle mass		
Soler et al. [85]	BB	25	MDDI	MDDI total	45.5±12.53	No difference between BB and NBBRT for MDDI total and all MDDI subscales
				Drive for size	19.1±6.1	
				Appearance intolerance	12.74±4.43	
				Functional impairment	13.52±4.53	
	NBBRT	151	MDDI	MDDI total	45.92±12.43	
				Drive for size	18.76±7.22	
				Appearance intolerance	12.44±3.12	
				Functional impairment	14.72±4.7	
Babusa et al. [55]	BB	60	MASS	MASS total	47.9±13.21	BB significantly higher (p<0.001) than undergraduate students on MASS total and all subscales except muscle satisfaction
				Bodybuilding dependence	12.8±4.18	
				Muscle checking	7.8±3.95	

				Substance use	8.9±4.18	
				Injury risk	9.2±3.42	
				Muscle satisfaction	9.1±3.24	
	Non-BB undergraduate students	60	MASS	MASS total	33.2±7.88	
				Bodybuilding dependence	7.2±3.01	
				Muscle checking	5.2±2.32	
				Substance use	4.9±1.43	
				Injury risk	6.5±2.47	
				Muscle satisfaction	9.2±2.67	
Davies et al. [82]	BB, former AAS users	30	MDI	Dietary behaviour	21.9	No significant differences between former AAS-users and current AAS users
				Supplement use	17.1	
				Pharmacological use	6.2	
				Exercise dependence	19.2	
				Size/symmetry	21.7	
				Physique protection	14.2	
	BB, current AAS users	30	MDI	Dietary behaviour	21.2	
				Supplement use	16.5	
				Pharmacological use	7.6	
				Exercise dependence	17.8	

	Size/symmetry	20.5
	Physique protection	13.9

Data are presented as mean ± SD. BB, bodybuilder; NBBRT, non-bodybuilder resistance trainer; AAS, anabolic androgenic steroid; MDI, Muscle Dysmorphia Inventory; MASS, Muscle Appearance Satisfaction Scale; MDDI, Muscle Dysmorphic Disorder Inventory; BIG, Bodybuilder Image Grid; MD, muscle dysmorphia; SD, standard deviation

Two studies used the MASS to assess MD in BB [55,86] (Table 3.8). One study used NBBRT as a comparison group [86], while the second study compared BB to non-training controls [55]. The MASS total score showed a significant ES of BB in both studies (ES range: 1.34 to 1.61, $p < 0.001$) [55,86]. The ES for bodybuilding dependence significantly favoured BB in both studies (ES range: 1.33 to 1.53, $p < 0.001$) [55,86]. Both also showed a significant positive ES of BB on muscle checking (ES range: 0.8 to 1.2, $p < 0.001$) [55,86]. The substance use ES significantly favoured BB (ES = 1.27, $p < 0.001$) [55,86]. For injury risk, both studies showed a significant positive ES of BB (ES range: 0.9 to 1.25, $p < 0.001$) [55,86]. The ES for muscle satisfaction significantly favoured BB in one of the studies (ES range: -0.03 to 0.53, $p < 0.001$) [86].

Table 3.4. Muscle dysmorphia assessment results of non-bodybuilder resistance trainers

Reference	Group	n	Tool	Subscale	Results	Main findings
de Lima et al. [98]	NBBRT	23	MASS			n=4 (17%) demonstrated positive risk for MD
Cafri et al. [102]	NBBRT, MD	23	MASS	Bodybuilding dependence	26.07±3.63	MD group significantly higher (p<0.01) on
			MDDI	Muscle checking	20.13± 5.18	bodybuilding dependence, muscle checking,
				Substance use	16.53±7.31	muscle satisfaction and functional impairment
				Injury risk	13.87±5.14	subscales than non-MD
				Muscle satisfaction	15.8±3.55	
				Functional impairment	21.67±3.48	
	NBBRT, no MD	28	MASS	Bodybuilding dependence	19.53±5.56	
			MDDI	Muscle checking	13.67±5.61	
				Substance use	12.25±4.02	
				Injury risk	11.33±3.55	
				Muscle satisfaction	12.3±4.1	
				Functional impairment	13.44±3.38	
Giardino et al. [81]	NBBRT, Mexican men	35	MASS	MASS total	25.77±12.48	Mexican men significantly higher (p=0.043)
	NBBRT, Mexican women	11	MASS	MASS total	17.26±9.06	MASS total than Mexican women
	NBBRT, US men	43	MASS	MASS total	29.42±13.1	US men significantly higher (p=0.002) MASS
	NBBRT, US women	24	MASS	MASS total	19.44±11.1	total than US women

Nieuwoudt et al. [99]	NBBRT	648	MASS	MASS total	66.5±19.05	n=110 (17%) at risk for MD
				Bodybuilding dependence	18.46±6.21	
				Muscle checking	12.43±5.55	
				Substance use	11.63±4.4	
				Injury risk	12.61±4.24	
				Muscle satisfaction	12.61±4.24	
Robert et al. [97]	NBBRT M	55	MASS	MASS total	42.56±12.35	Males significantly higher (p<0.05) than females on MASS total
	NBBRT F	59	MASS	MASS total	38.76±9.31	
Thomas et al. [17]	NBBRT, training day	30	MDDI	Drive for size	15.87±3.67	All subscale scores significantly higher (p<0.05) on rest day than training day
				Appearance intolerance	8.97±2.79	
				Functional impairment	9.47±3.8	
	NBBRT, rest day	30	MDDI	Drive for size	18.0±4.4	
				Appearance intolerance	10.1±3.47	
				Functional impairment	10.2±4.36	
Tod et al. [100]	NBBRT	294	MASS	Bodybuilding dependence	12.15±5.5	
				Muscle satisfaction	8.49±2.64	
Valdes et al. [101]	NBBRT M	112	ACQ		56.3% mild concern 43.7% moderate concern	

	NBBRT F	88	ACQ		53.4% mild concern 46.6% moderate concern	
Kanayama et al. [83]	NBBRT, AAS users	48	MDQ	Preoccupied with body size	n=43(90%)	More AAS users answered yes to first two questions than non-users
				Always covers body with clothes	n=19(40%)	
				Gives up pleasurable activities	n=11(23%)	
	NBBRT, AAS non-users	41	MDQ	Preoccupied with body size	n=26(63%)	
				Always covers body with clothes	n=5(12%) n=3(7%)	
				Gives up pleasurable activities		
Olivardia et al. [47]	NBBRT, MD	24	MDSQ	Weigh-ins per week	5.0±3.9	MD group showed significantly more symptoms ($p<0.001$) of muscle dysmorphia than non-MD group
				Mirror checks per day	9.2±7.5	
				Minutes per day preoccupied with thoughts of being too small	325.0±337	
	NBBRT, no MD	30	MDSQ	Weigh-ins per week	2.0±2.0	

				Mirror checks per day	3.4±3.3	
				Minutes per day preoccupied with thoughts of being too small	41.2±173	
Segura-Garcia et al. [88]	Men gaining weight	52	MDI	Dietary behaviour	13.5±7	No significant difference between men gaining weight and men losing weight on all subscales
				Supplement use	10±6.5	
				Pharmacological use	3.3±2.5	
				Exercise dependence	16.5±5.5	Men gaining weight significantly higher (p<0.001) than female groups on all MDI subscales except pharmacological use and physique protection
				Size/symmetry	14±7.5	
				Physique protection	10±5.5	
	Men losing weight	34	MDI	Dietary behaviour	12.5±6.25	
				Supplement use	7.5±5.5	Men losing weight significantly higher (p<0.001) than ED group on exercise dependence
				Pharmacological use	3.5±2	
				Exercise dependence	13.7±5.75	
				Size/symmetry	12±5.75	
				Physique protection	11.2±5.5	
	Women losing weight	48	MDI	Dietary behaviour	9.75±4.75	
				Supplement use	5±2.75	
				Pharmacological use	3.8±2	

				Exercise dependence	11.6±4.5
				Size/symmetry	8.6±4
				Physique protection	9.45±4.5
	Women ED	20	MDI	Dietary behaviour	9±3.5
				Supplement use	4.7±2.1
				Pharmacological use	3.5±1
				Exercise dependence	8.6±4.75
				Size/symmetry	9±4
				Physique protection	9.4±3.5

Data are presented as mean ± standard deviation (except where otherwise indicated). NBBRT, non-bodybuilder resistance trainer; MASS, Muscle Appearance Satisfaction Scale; MD, Muscle dysmorphia; US, United States; MDDI, Muscle Dysmorphic Disorder Inventory; ACQ, Adonis Complex Questionnaire; MDQ, Muscle Dysmorphia Questionnaire; MDSQ, Muscle Dysmorphia Symptom Questionnaire; MDI, Muscle Dysmorphia Inventory; ED, Eating disorder; M, male; F, female; AAS, anabolic-androgenic steroid

One study used the BIG to assess MD symptoms in BB and non-training controls [50]. The ES showed BB scored higher on all muscle indices (ES range: 0.07 to 2.53), all of which were significant ($p < 0.001$) except the subscale assessing 'most attractive to women'. There was a significant negative ES for BB on all indices related to fat mass (ES range: -0.87 to -1.93, $p < 0.001$).

Meta-analysis

Meta-analyses were conducted on studies comparing BB to NBBRT using the MDI ($n = 5$) [15,48,51,84,86]. Meta-analysis of studies using other MD instruments was considered implausible as too few used other instruments, and they contained subscales that were too heterogeneous to pool, thus including these studies in the analyses would introduce bias [87]. The pooled overall estimates for each subscale consistently indicated medium to large mean differences, with higher MD symptoms in BB relative to NBBRT samples (Figures 3.2-3.7). A large pooled ES was evident for dietary behaviour (ES = 1.12, 95% CI: 0.69 to 1.55; $p < 0.001$). Assessment of heterogeneity yielded a significant finding ($Q = 27.41$; $df = 4$; $p < 0.001$), with $I^2 = 85.41\%$. A large pooled ES was evident for supplement use (ES = 1.08, 95% CI: 0.31 to 1.84; $p = 0.006$), and there was evidence of significant heterogeneity ($Q = 88.61$; $df = 4$; $p < 0.001$; $I^2 = 95.49\%$).

Reference	n	ES (95% CI)	*p* value
Baghurst et al. [51]	65	0.66 (0.35 to 0.97)	<0.001
Cella et al. [87]	119	0.16 (1.28 to 1.89)	<0.001
Hale et al. [48]	26	1.96 (1.25 to 2.66)	<0.001
Lantz et al. [15]	100	0.83 (0.52 to 1.15)	<0.001
Skemp et al. [85]	51	0.83 (0.47 to 1.12)	<0.001
Pooled estimate		1.12 (0.69 to 1.55)	<0.001

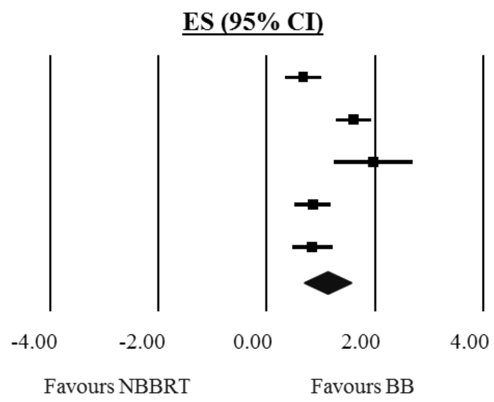

Figure 3.2 Meta-analysis of the pooled effect of BB *vs.* NBBRT on the dietary behaviour subscale of the Muscle Dysmorphia Inventory. Data are presented as standardised mean difference (ES) and 95% confidence interval (95% CI). NBBRT, Non-bodybuilding resistance trainer; BB, Bodybuilder; ES, effect size

Reference	n	ES (95% CI)	*p* value
Baghurst et al. [51]	65	0.6 (0.3 to 0.91)	<0.001
Cella et al. [87]	119	1.97 (1.64 to 2.29)	<0.001
Hale et al. [48]	26	2.35 (1.59 to 3.11)	<0.001
Lantz et al. [15]	100	0.1 (-0.21 to 0.41)	0.517
Skemp et al. [85]	51	0.55 (0.2 to 0.91)	0.002
Pooled estimate		1.08 (0.31 to 1.84)	0.006

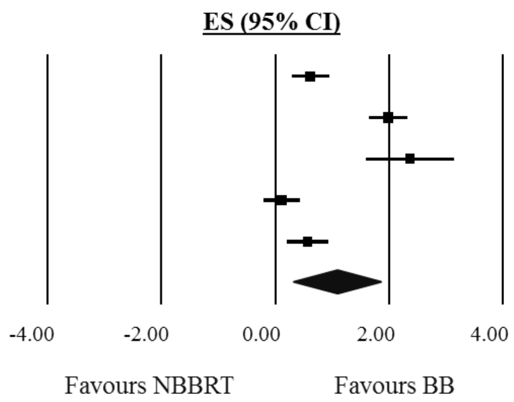

Figure 3.3 Meta-analysis of the pooled effect of BB *vs.* NBBRT on the supplement use subscale of the Muscle Dysmorphia Inventory. Data are presented as standardised mean difference (ES) and 95% confidence interval (95% CI). NBBRT, Non-bodybuilding resistance trainer; BB, Bodybuilder; ES, effect size

A large pooled ES was also evident for exercise dependence (ES = 1.1, 95% CI: 0.12 to 2.08; $p = 0.03$), with evidence of significant heterogeneity ($Q = 80.17$; $df = 3$; $p < 0.001$; $I^2 = 96.23\%$). A medium pooled ES was evident for pharmacological use (ES = 0.53, 95% CI: 0.14 to 0.91; $p = 0.007$), with heterogeneity significant ($Q = 24.62$; $df = 4$; $p < 0.001$; $I^2 = 83.75\%$).

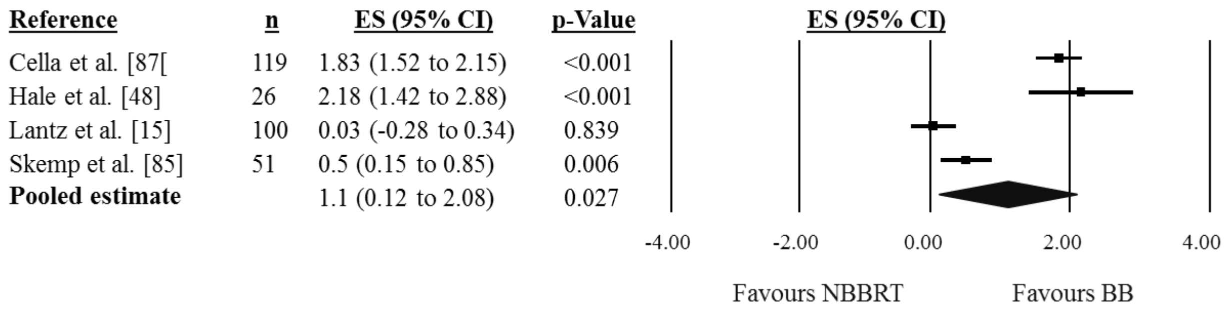

Figure 3.4 Meta-analysis of the pooled effect of BB *vs.* NBBRT on the exercise dependence subscale of the Muscle Dysmorphia Inventory. Data are presented as standardised mean difference (ES) and 95% confidence interval (95% CI). NBBRT, Non-bodybuilding resistance trainer; BB, Bodybuilder; ES, effect size

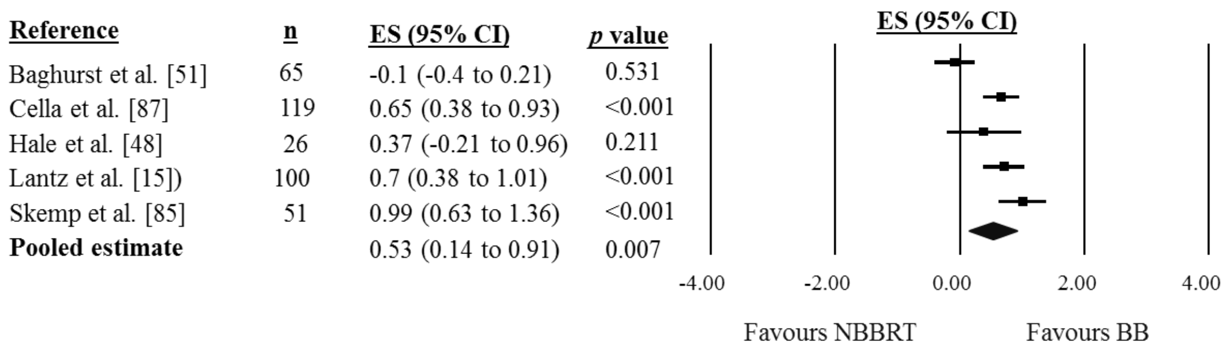

Fig. 3.5 Meta-analysis of the pooled effect of BB *vs.* NBBRT on the pharmacological use subscale of the Muscle Dysmorphia Inventory. Data are presented as standardised mean difference (ES) and 95% confidence interval (95% CI). NBBRT, Non-bodybuilding resistance trainer; BB, Bodybuilder; ES, effect size

A large pooled ES was evident for size/symmetry (ES = 0.83, 95% CI: 0.2 to 1.46; p = 0.01), with evidence of significant heterogeneity (Q = 63.48; df = 4; p < 0.001; I^2 = 93.7%). A medium pooled ES was also evident for physique protection (ES = 0.59, 95% CI: 0.2 to 0.98; p = 0.003), with heterogeneity significant (Q = 25.32; df = 4; p < 0.001; I^2 = 84.2%).

Reference	n	ES (95% CI)	p-Value
Baghurst et al. [51]	65	0.09 (-0.21 to 0.39)	0.557
Cella et al. [87]	119	1.63 (1.32 to 1.94)	<0.001
Hale et al. [48]	26	1.67 (1.0 to 2.35)	<0.001
Lantz et al. [15]	100	0.5 (0.19 to 0.81)	0.002
Skemp et al. [85]	51	0.37 (0.02 to 0.72)	0.040
Pooled estimate		0.83 (0.2 to 1.46)	0.010

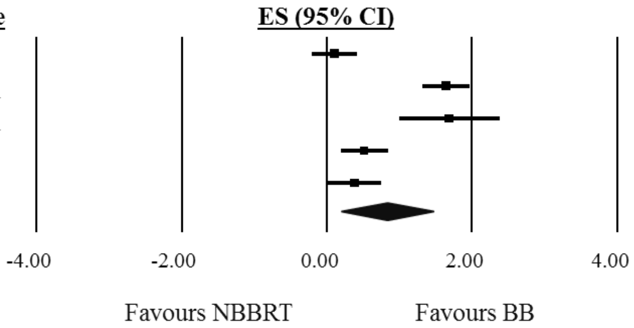

Figure 3.6 Meta-analysis of the pooled effect of BB *vs.* NBBRT on the size/symmetry subscale of the Muscle Dysmorphia Inventory. Data are presented as standardised mean difference (ES) and 95% confidence interval (95% CI). NBBRT, Non-bodybuilding resistance trainer; BB, Bodybuilder; ES, effect size

Reference	n	ES (95% CI)	*p* value
Baghurst et al. [51]	65	0.07 (-0.23 to 0.37)	0.654
Cella et al. [87]	119	1.13 (0.84 to 1.42)	<0.001
Hale et al. [48]	26	0.7 (0.1 to 1.3)	0.021
Lantz et al. [15]	100	0.5 (0.19 to 0.81)	0.002
Skemp et al. [85]	51	0.58 (0.23 to 0.94)	0.001
Pooled estimate		0.59 (0.2 to 0.98)	0.003

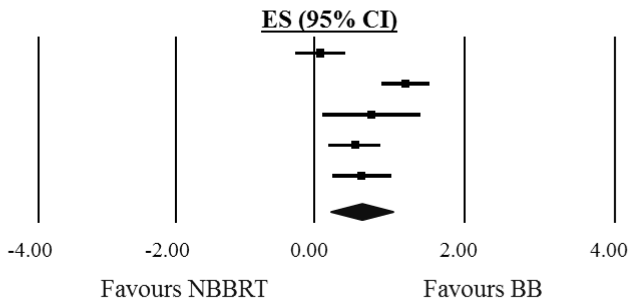

Figure 3.7 Meta-analysis of the pooled effect of BB *vs.* NBBRT on the physique protection subscale of the Muscle Dysmorphia Inventory. Data are presented as standardised mean difference (ES) and 95% confidence interval (95% CI). NBBRT, Non-bodybuilding resistance trainer; BB, Bodybuilder; ES, effect size

Due to the small study number, further investigations into the heterogeneity were not conducted.

Do non-bodybuilder resistance trainers display more muscle dysmorphia symptoms than non-resistance trained individuals?

One study compared symptoms of MD in resistance trained and non-resistance trained individuals. Using the MDI, Segura-García, *et al.* [88] found no significant differences in MD symptoms between males training to gain weight and males training to lose weight. However, males training to gain weight scored significantly higher on all MDI subscales except physique protection and pharmacological use than females training to lose weight and females with a diagnosed eating disorder (anorexia nervosa and bulimia nervosa).

Table 3.5. Muscle dysmorphia and psychological traits in bodybuilders and non-bodybuilder resistance trainers

Reference	Group	N	Tool	Subscale	Results	Main findings
Babusa et al. [55]	BB	60	MASS	MASS total	47.9±13.21	No perfectionism-MD correlation. BB higher perfectionism than undergraduate students
			EDI	Perfectionism	6.3±3.85	
	Non-BB undergraduate students	60		MASS total	33.2±7.88	
				Perfectionism	4.1±2.89	
Boyda et al. [89]	BB	51	MASS	MASS total	59.09±14.82	Anxiety correlated with MD (r=0.42, p<0.01)
			DASS	Depression		
				Anxiety		
Castro-Lopez et al. [79]	BB	154	ACQ	ACQ total		Neuroticism correlated with MD (r=0.38, p<0.001)
			NEO 5-FPI	Neuroticism	28.21±7.3	
				Extraversion	39.59±5.36	

Gonzalez-Marti et al. [90]	BB, NBBRT	734	MASS PSCS	MASS total Bodybuilding dependence Muscle checking Substance use Injury risk Muscle satisfaction General self-concept General physical self-concept		General self-concept (r range: -0.2 to -0.5, p<0.01) and general physical self-concept (r range: -0.16 to -0.53, p<0.01) negatively correlated with MASS total and all subscales
Lopez-Barajes et al. [91]	BB	154	ACQ STAI SCQ-5	ACQ total State anxiety Trait anxiety Emotional self-concept Academic-occupational self-concept	18.67±3.63	MD correlated with state anxiety (r=0.25, p<0.01), emotional self-concept (r=-0.23, p<0.01) and academic-occupational self-concept (r=0.14, p<0.05)
Wolke et al. [92]	BB	100	MDI RSES SC90	MDI total Self esteem Depression Anxiety	25.28±12.83 32.88±5.24 10.88±10.06 7.87±7.15	MD correlated with depression (r=0.38, p<0.01), anxiety (r=0.32, p<0.01) Negative correlation with self-esteem (r=-0.46, p<0.01)

Babusa et al. [49]	Weightlifters	289	MASS RSES	Muscle satisfaction Substance use Injury risk Muscle checking Bodybuilding dependence Self-esteem		Self-esteem negatively correlated with all MASS subscales except injury risk (r range: -0.12 to -0.31, p<0.05)
Hildebrandt et al. [93]	Dysmorphic	40	MDDI BIG-O SPAS	Drive for size Appearance intolerance Functional impairment Desired muscle Desired fat Social physique anxiety	14.87±4.12 13.67±5.17 15.49±4.37 0.72±0.72 1.3±0.97 34.72±7.34	Dysmorphic group higher than all other groups on each MDDI subscale Significantly higher (p<0.001) than all groups except fat concern group on social physique anxiety
	Muscular concern	63		Drive for size Appearance intolerance Functional impairment Desired muscle Desired fat Social physique anxiety	11.31±4.8 7.06±3.73 9.51±4.83 1.12±0.4 0.69±0.98 28.13±5.23	

	Fat concern	66	Drive for size	5.5±4.82
			Appearance intolerance	12.3±5.12
			Functional impairment	12.28±5.11
			Desired muscle	-0.29±0.71
			Desired fat	1.36±0.93
			Social physique anxiety	32.98±6.29
	Normal-behavioural	38	Drive for size	5.47±3.8
			Appearance intolerance	2.97±2.69
			Functional impairment	6.63±4.6
			Desired muscle	-0.13±0.41
			Desired fat	0.6±0.94
			Social physique anxiety	22.16±3.46
	Normal	30	Drive for size	4.8±3.25
			Appearance intolerance	2.17±2.59
			Functional impairment	5.2±2.72
			Desired muscle	0.5±0.73
			Desired fat	0.37±1.05
			Social physique anxiety	23.46±3.06

Kuennen et al. [94]	Resistance trained	49	MDI	Dietary behaviour	3.38±1.13	Negative association between self-esteem and size/symmetry (r=-0.42, p<0.01), physique protection (r=-0.39, p<0.01).
			RSES	Supplement use	3.18±1.41	
			NPI	Pharmacological use	1.13±0.3	
			MPS	Exercise dependence	4.42±0.87	Perfectionism associated with exercise dependence (r=0.35, p<0.05)
				Size/symmetry	3.59±1.1	
				Physique protection	2.04±0.68	
				Self-esteem	0.95±0.66	
				Narcissism	19.82±6.64	
				Perfectionism	2.98±0.49	
Kim et al. [80]	Resistance trained	429	MDI			Depression associated with MD (r=0.53, p<0.001)
			BDI			
Maida et al. [95]	Resistance trained	106	MDSQ		n=26(25%) heightened MD symptoms	Perfectionism (r=0.41, p<0.01), depression (r=0.36, p<0.01), anxiety (r=0.39, p<0.01) each associated with MD
			EDI	Perfectionism	5.2±0.16	
			BSI	Depression	0.21±0.33	
				Anxiety	0.26±0.31	

Thomas et al. [96]	Resistance trained	146	MDI MASS-6 SPAS	Dietary behaviour Supplement use Exercise dependence Size/symmetry Physique protection MASS-6 Social physique anxiety	2.91±1.14 3.02±1.38 3.7±1.1 3.3±1.17 2.1±0.82 2.88±0.91 2.43±0.8	Social physique anxiety associated with supplement use ($r=0.26$, $p<0.05$), size/symmetry ($r=0.36$, $p<0.05$), physique protection ($r=0.75$, $p<0.05$), and overall MD ($r=0.29$, $p<0.05$)

Data are presented as mean ± SD (except where otherwise indicated). BB, bodybuilder; NBBRT, non-bodybuilder resistance trainer; MASS, Muscle Appearance Satisfaction Scale; ACQ, Adonis Complex Questionnaire; MDI, Muscle Dysmorphia Inventory; MDDI, Muscle Dysmorphic Disorder Inventory; BIG-O, Bodybuilder Image Grid Original; MDSQ, Muscle Dysmorphia Symptom Questionnaire; MASS-6, Muscle Appearance Satisfaction Scale 6 items; EDI, Eating Disorder Inventory; DASS, Depression Anxiety Stress Scale; NEO 5-FPI, NEO 5 Factor Personality Inventory; PSCS, Physical Self-Concept Scale; STAI, State Trait Anxiety Inventory; SCQ-5, Self-Concept Questionnaire 5; RSES, Rosenberg Global Self-Esteem Scale; SC90, Symptom Checklist 90; SPAS, Social Physique Anxiety Scale; NPI, Narcissistic Personality Inventory; MPS, Multidimensional Perfectionism Scale; BDI, Beck Depression Inventory; BSI, Brief Symptom Inventory; MD, muscle dysmorphia

Table 3.6. Effect size of differences in Muscle Dysmorphia Inventory subscale scores between bodybuilders and non-bodybuilder resistance trained individuals

Reference	Comparison	Scale	Subscale	Hedges' *g*	*p* value
Baghurst et al. [51]	Natural BB vs NBBRT(WTP)	MDI	Dietary behaviour	0.66±0.16 [0.35 to 0.97]	<0.001
			Supplement use	0.6±0.16 [0.28 to 0.91]	<0.001
			Pharmacological use	-0.1±0.16 [-0.4 to 0.21]	0.531
			Size/symmetry	0.09±.016 [-0.21 to 0.39]	0.557
			Physique protection	0.07±0.16 [-0.23 to 0.37]	0.654
Cella et al. [86]	BB vs NBBRT (non-BB)	MDI	Dietary behaviour	1.58±0.16 [1.28 to 1.89]	<0.001
			Supplement use	1.97±0.17 [1.64 to 2.29]	<0.001
			Pharmacological use	0.65±0.14 [0.38 to 0.93]	<0.001
			Exercise dependence	1.83±0.16 [1.52 to 2.15]	<0.001
			Size/symmetry	1.63±0.16 [1.32 to 1.94]	<0.001
			Physique protection	1.13±0.15 [0.84 to 1.42]	<0.001
Hale et al. [48]	BB(expert) vs NBBRT(FL)	MDI	Dietary behaviour	1.96±0.36 [1.25 to 2.66]	<0.001
			Supplement use	2.35±0.39 [1.59 to 3.11]	<0.001
			Pharmacological use	0.37±0.3 [-0.21 to 0.96]	0.211
			Exercise dependence	2.15±0.37 [1.42 to 2.88]	<0.001
			Size/symmetry	1.67±0.35 [1.0 to 2.35]	<0.001

			Physique protection	0.7±0.31 [0.1 to 1.3]	0.021
Lantz et al. [15]	BB vs NBBRT(PL)	MDI	Dietary behaviour	0.83±0.16 [0.52 to 1.15]	<0.001
			Supplement use	0.1±0.16 [-0.21 to 0.41]	0.517
			Pharmacological use	0.7±0.16 [0.38 to 1.0]	<0.001
			Exercise dependence	0.03±0.16 [-0.28 to 0.34]	0.839
			Size/symmetry	0.5±0.16 [0.19 to 0.81]	0.002
			Physique protection	0.5±0.16 [0.19 to 0.81]	0.002
Skemp et al. [84]	BB(AE) vs NBBRT(PE)	MDI	Dietary behaviour	0.83±0.18 [0.47 to 1.19]	<0.001
			Supplement use	0.55±0.18 [0.2 to 0.91]	0.002
			Pharmacological use	0.99±0.19 [0.63 to 1.36]	<0.001
			Exercise dependence	0.5±0.18 [0.15 to 0.85]	0.006
			Size/symmetry	0.37±0.18 [0.02 to 0.72]	0.04
			Physique protection	0.58±0.18 [0.23 to 0.94]	0.001

Data are presented as standardised mean difference (ES) ± SE (95% CI). BB, bodybuilder; NBBRT, non-bodybuilder resistance trainer; WTP, weight trainers for physique; FL, fitness lifters; PL, powerlifters; AE, appearance enhancement; PE, performance enhancement; MDI, Muscle Dysmorphia Inventory; ES, effect size; SE, standard error; CI, confidence interval

Table 3.7. Effect size of differences in Muscle Dysmorphic Disorder Inventory subscale scores between bodybuilders and non-bodybuilders

Reference	Comparison	Scale	Subscales	Hedges' *g*	*p* value
Santarnecchi et al. [50]	BB(competing) vs controls (non-training)	MDDI	Total	3.62±0.3 [3.04 to 4.21]	<0.001
			Drive for size	2.47±0.24 [2.0 to 2.95]	<0.001
			Appearance intolerance	1.2±0.2 [0.81 to 1.59]	<0.001
			Functional impairment	2.95±0.26 [2.43 to 3.47]	<0.001
Soler et al. [85]	BB vs NBBRT (gym goers)	MDDI	Total	0.03±0.22 [-0.39 to 0.46]	0.877
			Drive for size	-0.05±0.22 [-0.48 to 0.37]	0.802
			Appearance intolerance	-0.07±0.22 [-0.49 to 0.35]	0.745
			Functional impairment	0.26±0.22 [-0.16 to 0.69]	0.223

Data are presented as standardised mean difference (ES) ± SE (95% CI). BB, bodybuilder; NBBRT, non-bodybuilder resistance trainer; MDDI, Muscle Dysmorphia Disorder Inventory; ES, effect size; SE, standard error; CI, confidence interval

Table 3.8. Effect size of differences in Muscle Appearance Satisfaction Scale subscale scores between bodybuilders and non-bodybuilders

Reference	Comparison	Scale	Subscales	Hedges' *g*	*p* value
Babusa et al. [55]	BB (non-competitive) vs controls (students, non-bodybuilders)	MASS	Total	1.34±0.2 [0.95 to 1.74]	<0.001
			Bodybuilding dependence	1.53± 0.21 [1.12 to 1.93]	<0.001
			Muscle checking	0.8±0.19 [0.43 to 1.17]	<0.001
			Substance use	1.27±0.2 [0.88 to 1.66]	<0.001
			Injury	0.9±0.19 [0.53 to 1.27]	<0.001
			Muscle satisfaction	-0.03±0.18 [-0.39 to 0.32]	0.854
Cella et al. [86]	BB vs NBBRT (non-BB)	MASS	Total	1.61±0.16 [1.3 to 1.92]	<0.001
			Bodybuilding dependence	1.33±0.15 [1.03 to 1.62]	<0.001
			Muscle checking	1.2±0.15 [0.91 to 1.49]	<0.001
			Substance use	1.27±0.15 [0.97 to 1.56]	<0.001
			Injury	1.25±0.15 [0.96 to 1.56]	<0.001
			Muscle satisfaction	0.53±0.14[0.26 to 0.8]	<0.001

Data are presented as standardised mean difference (ES) ± SE (95% CI). BB, bodybuilder; NBBRT, non-bodybuilder resistance trainer; MASS, Muscle Appearance Satisfaction Scale; ES, effect size; SE, standard error; CI, confidence interval

Does bodybuilding calibre affect muscle dysmorphia symptoms?

One study used the MDDI and BIG to compare symptoms of MD between competitive and non-competitive BB [50]. The ES significantly favoured competitive BB on MDDI total score, drive for size and functional impairment subscales (ES range: 1.21 to 1.42, $p < 0.001$), but significantly favoured non-competitive BB on the appearance intolerance subscale (ES: -1.09, $p < 0.001$; Table 3.9). The competitive BB showed a positive ES for each of the BIG indices related to muscle (ES range: 0.31 to 1.65), of which three – current muscle, ideal muscle and most attractive muscle – were significant ($p < 0.001$). The competitive BB also showed a significant negative ES on all four indices related to fat – current, ideal, most attractive and most attractive to women (ES range: -0.79 to -1.22, $p < 0.001$) – suggesting lower current, ideal, most attractive and most attractive to women body fat percentage than non-competitive BB. One study [48] compared symptoms of MD between expert (defined as having competed in 10 or more bodybuilding competitions) and novice (defined as having competed in three or less competitions) BB, using the MDI, noting a greater effect size in the dietary behaviour, supplement use, exercise dependence and size/symmetry subscales amongst expert BB (ES range: -0.16 to 0.76), however only supplement use and exercise dependence were significant ($p \leq 0.01$; Table 3.10).

Table 3.9. Effect size of differences in Muscle Dysmorphic Disorder Inventory subscale scores between competitive and non-competitive bodybuilders

Reference	Comparison	Scale	Subscales	Hedges' *g*	*p* value
Santarnecchi	BB(competing) vs	MDDI	Total	1.21±0.2 [0.82 to 1.6]	<0.001
et al. [50]	BB(non-competing)		Drive for size	1.23±0.2 [0.84 to 1.62]	<0.001
			Appearance intolerance	-1.09±0.2 [-1.47 to -0.71]	<0.001
			Functional impairment	1.42±0.2 [1.02 to 1.82]	<0.001

Data are presented as standardised mean difference (ES) ± SE (95% CI). BB, bodybuilder; MDDI, Muscle Dysmorphic Disorder Inventory; ES, effect size; SE, standard error; CI, confidence interval

Table 3.10. Effect size of difference in Muscle Dysmorphia Inventory subscale scores between expert and novice bodybuilders

Reference	Comparison	Scale	Subscale	Hedges' *g*	*p* value
Hale et al. [48]	BB(expert) vs BB(novice)	MDI	Dietary behaviour	0.53±0.27 [-0.01 to 1.06]	0.053
			Supplement use	0.76±0.28 [0.22 to 1.3]	0.006
			Pharmacological use	-0.03±0.27 [-0.55 to 0.49]	0.907
			Exercise dependence	0.71±0.28 [0.17 to 1.24]	0.01
			Size/symmetry	0.25±0.27 [-0.27 to 0.78]	0.348
			Physique protection	-0.16±0.27 [-0.68 to 0.37]	0.559

Data are presented as standardised mean difference (ES) ± SE (95% CI). BB, bodybuilder; MDI, Muscle Dysmorphia Inventory; ES, effect size; SE, standard error; CI, confidence interval

What psychological features are associated with muscle dysmorphia in bodybuilders and non-bodybuilder resistance trainers?

Of the studies included in analyses, six examined the association (reporting correlation coefficient, *r*) between psychological features and MD symptoms in BB [55,79,89-92] (Table 3.5). A wide range of features were examined, although many of these were investigated in only one study [55,79,92]. Features most commonly examined were self-concept (*n* = 4), including general, physical, emotional and academic-occupational self-concept [90,91], and anxiety (*n* = 3) [89,91,92]. Other features reported were self-esteem [92], depression [89], neuroticism [79], extraversion [79] and perfectionism [55] (*n* = 1 for each). Features positively correlated with MD were academic-occupational self-concept (*r* = 0.14), anxiety (*r* range: 0.32 to 0.42), depression (*r* range: 0.23 to 0.53) and neuroticism (*r* = 0.38) [89,91,92]. Factors negatively associated with muscle dysmorphia were general, physical and emotional self-concept, and self-esteem (*r* range: -0.18 to -0.57) [90-92]. No association was found between extraversion and MD [79], or perfectionism and MD [55].

Six of 31 studies examined psychological features and MD in NBBRT [49,80,93-96] (see Table 3.5). Features most commonly reported were anxiety (*n* = 3) [93,95,96], perfectionism (*n* = 2) [94,95], self-esteem (*n* = 2) [49,94], and depression (*n* = 2) [80,95]. The final feature reported was narcissism (*n* = 1) [94]. Features positively associated with MD were anxiety and social physique anxiety (*r* range: 0.26 to 0.75) [93,95,96], perfectionism (*r* range: 0.35 to 0.57) [94,95], and depression (*r* range: 0.36 to 0.53) [80,95]. Self-esteem was negatively associated with MD (*r* range: -0.12 to -0.42) [49,94]. No association was reported between narcissism and MD [94].

Do anabolic-androgenic steroid users display more muscle dysmorphia symptoms than non-anabolic-androgenic steroid users?

Four of 31 studies compared BB based on steroid use (AAS users versus non-users) [51,55,82,86], using either the MDI (n = 3) or the MASS (n = 2). Insufficient data were available in these studies to calculate mean difference and 95% CI. There was a lack of consistency in differences between users and non-users across these papers. Cella, Iannaccone and Cotrufo [86] identified that steroid users scored higher than non-users on all MDI subscales except exercise dependence, while Baghurst and Lirgg [51] reported higher pharmacological use in non-natural BB. Steroid users scored higher than non-users on the MASS total [55] and on all MASS subscales except muscle satisfaction [86]. Conversely, Davies and Smith [82] showed no significant difference on all MDI subscales between current steroid users and former steroid users.

Kanayama, Barry, Hudson and Pope [83] compared resistance trained individuals based on AAS use on the three item MD Questionnaire and found AAS users responded significantly more affirmatively to MD symptoms questions than non-users.

Do male and female non-bodybuilder resistance trainers display different muscle dysmorphia symptoms?

Three of 31 studies compared MD symptoms in male and female NBBRT [81,84,97]. The MASS total score showed an ES favouring males in two studies [81,97] (ES range: 0.35 to 0.79), one of which was significant ($p \leq 0.04$) [81]. Skemp, Mikat, Schenck and Kramer [84] found a positive ES for males on the supplement use, pharmacological use, size/symmetry and physique protection subscales of the MDI (ES range: 0.28 to 0.99), and with significance for pharmacological use and size/symmetry ($p = 0.001$) [84]. There was no difference for dietary behaviour and exercise dependence (ES= 0) [84] (Table 3.11).

Do muscle dysmorphia symptoms vary with the proximity of resistance training?

One of 31 studies examined the effect of proximity of resistance exercise on symptoms of MD (Table 3.12). Thomas, Tod and Lavallee [17] used the MDDI to assess symptoms of MD in resistance trained males on both a training and a rest day, finding a significant increase in scores for the drive for size subscale of the MDDI on the rest day (ES: 0.52, $p < 0.05$). The appearance intolerance and functional impairment subscales also both showed an ES favouring higher scores on the rest day, however neither of these was significant (ES range: 0.18 to 0.35).

Table 3.11. Effect size of difference in Muscle Appearance Satisfaction Scale and Muscle Dysmorphia Inventory subscale scores between male and female non-bodybuilder resistance trainers (NBBRT)

Reference	Comparison	Scale	Subscale	Hedges' *g*	*p* value
Giardino et al. [81]	US males vs US females	MASS	Total	0.79±0.26 [0.28 to 1.31]	0.002
Giardino et al. [81]	Mexican males vs Mexican females	MASS	Total	0.71±0.35 [0.03 to 1.39]	0.041
Robert et al. [97]	Males vs females	MASS	Total	0.35±0.19 [-0.02 to 0.72]	0.064
Skemp et al. [84]	Males vs females	MDI	Dietary behaviour	0±0.28 [-0.54 to 0.54]	1.0
			Supplement use	0.36±0.28 [-0.19 to 0.9]	0.201
			Pharmacological use	-0.99±0.29 [-1.56 to -0.41]	0.001
			Exercise dependence	0±0.28 [-0.54 to 0.54]	0.314
			Size/symmetry	0.97±0.29 [0.4 to 1.54]	0.001
			Physique protection	0.28±0.28 [-0.26 to 0.82]	0.314

Data are presented as standardised mean difference (ES) ± SE (95% CI). US, United States of America; NBBRT, non-bodybuilder resistance trainer; MASS, Muscle Appearance Satisfaction Scale; MDI, Muscle Dysmorphia Inventory; ES, effect size; SE, standard error; CI, confidence interval

Table 3.12. Effect size of difference in Muscle Dysmorphic Disorder Inventory subscale scores between training day and rest day in non-bodybuilder resistance trainers (NBBRT)

Reference	Comparison	Scale	Subscale	Hedges' *g*	*p* value
Thomas et al. [17]	Training day vs rest day (NBBRT)	MDDI	Drive for size	0.52±0.26 [0.01 to 1.03]	0.045
			Appearance intolerance	0.35±0.26 [-0.15 to 0.86]	0.168
			Functional impairment	0.18±0.26 [-0.32 to 0.68]	0.49

Data are presented as standardised mean difference (ES) ± SE (95% CI). NBBRT, non-bodybuilder resistance trainer; MDDI, Muscle Dysmorphic Disorder Inventory; ES, effect size; SE, standard error; CI, confidence interval

How severe are muscle dysmorphia symptoms?

Four of 31 studies reported the severity of MD symptoms in NBBRT, using the MASS (*n* = 3), and the Adonis Complex Questionnaire (*n* = 1) [98-101]. Mean scores were as follows: MASS total = 66.5/133, muscle checking = 11.62/28, bodybuilding dependence = 18.46/35, substance use = 12.43/28, injury risk = 11.63/21, muscle satisfaction = 12.61/21 [99]; bodybuilding dependence = 12.15/35, muscle satisfaction = 8.49/21 [100]. Based on MASS score, 17% were classified as 'at risk' of MD [99], and 17.4% demonstrated 'positive risk' for MD [98]. Using the Adonis Complex Questionnaire, Valdés, Lagos, Gedda, Cárcamo, Millapi and Webar [101] classified 56.3% of males as of 'mild concern' and 43.7% as of 'moderate concern', while 53.4% of females were of 'mild concern' and 46.6% of 'moderate concern'.

How do muscle dysmorphia symptoms vary between non-bodybuilder resistance trainers diagnosed with muscle dysmorphia and non-bodybuilder resistance trainers without muscle dysmorphia?

Three of the 31 studies grouped NBBRT based on a researcher determined MD diagnosis [47,102], or on variables associated with MD [93]. Three tools were used to assess MD symptoms in these studies – MDDI (*n* = 2), MASS (*n*= 1), MDSQ (*n* = 1). Muscle dysmorphic NBBRT scored higher than non-muscle dysmorphic NBBRT on the bodybuilding dependence, muscle checking and muscle satisfaction subscales of the MASS, the functional impairment subscale of the MDDI [102], all of the subscales of the MDDI [93], and on all questions of the MDSQ [47].

Table 3.13. Effect size of differences in Bodybuilder Image Grid subscale scores between bodybuilders and controls

Reference	Comparison	Scale	Subscale	Hedges' *g*	*p* value
Santarnecchi et al. [50]	BB(competing) vs BB (non-competing)	BIG	Current body type – fat	-0.79±0.19 [-1.16 to 0.42]	<0.001
			Current body type – muscle mass	1.11±0.2 [0.73-1.49]	<0.001
			Ideal body type – fat	-1.16±0.2 [-1.55 to -0.78]	<0.001
			Ideal body type – muscle mass	1.65±0.21 [1.23 to 2.06]	<0.001
			Most attractive body type – fat	-1.22±0.2 [-1.61 to -0.84]	<0.001
			Most attractive body type – muscle mass	1.2±0.2 [0.82 to 1.59]	<0.001
			Most attractive to women – fat	-0.84±0.19 [-1.21 to -0.46]	<0.001
			Most attractive to women – muscle mass	0.31±0.18 [-0.05 to 0.66]	0.095
Santarnecchi et al. [50]	BB(competing) vs Non-training controls	BIG	Current body type – fat	-1.28±0.2 [-1.67 to -0.89]	<0.001
			Current body type – muscle mass	2.53±0.24 [2.05 to 3.01]	<0.001

Ideal body type – fat	-1.93±0.21 [-2.15 to -1.31]	<0.001
Ideal body type – muscle mass	2.0±0.22 [1.56 to 2.44]	<0.001
Most attractive body type – fat	-1.53±0.21 [-2.01 to -1.19]	<0.001
Most attractive body type – muscle mass	1.49±0.21 [1.09 to 1.9]	<0.001
Most attractive to women – fat	-0.87±0.19 [-1.25 to -0.5]	<0.001
Most attractive to women – muscle mass	0.07±0.18 [-0.29 to 0.43]	0.697

Data are presented as standardised mean difference (ES) ± SE (95% CI). BB, bodybuilder; BIG, Bodybuilder Image Grid; ES, effect size; SE, standard error; CI, confidence interval

DISCUSSION

The aim of the present analysis was to firstly compare the existing evidence-base pertaining to MD symptomatology in BB versus NBBRT, and secondly, to identify psychological and other characteristics associated with MD symptomatology in these respective groups. We collated data from 1895 BB participants (male n = 1597, female n = 298), 3523 non-bodybuilding resistance trainers (male n = 3341, female n = 182), and 462 non-training controls (male n = 360, female n = 102) making this the largest systematic review of the literature on MD. Given the ongoing conflation of bodybuilding and MD, and the potential scope for pathologizing normative muscularity-enhancing pursuits, this review is important. Critically, results illustrate that BB reported greater MD symptomatology relative to NBBRT, with consistently larger effect sizes on most indices of MD symptomatology. With inconsistent use of measures of MD symptomatology precluding a large-scale meta-analysis, the data available from studies using the MDI [103] showed a moderate to large effect size (ES range: 0.53 to 1.12, $p \leq 0.01$) where BB reported greater MD symptom severity on all of the MDI subscales. Overall, the results indicate that BB have a higher risk of MD symptomatology when compared to NBBRT and non-training controls. This study also assessed psychological features linked with MD. Several features including anxiety, depression and perfectionism were positively and self-esteem negatively associated with MD. These associations were similar in both BB and NBBRT. However, the association between the psychological features and MD was not strong ($r \leq 0.53$) and a minority of the papers assessed psychological features indicating that there is scope to explore this further. As anticipated, the male and female BB had a higher BMI (male BB: 29.7 $kg \cdot m^{-2}$, female BB: 27 $kg \cdot m^{-2}$) than the NBBRT (male NBBRT: 27.2 $kg \cdot m^{-2}$, female NBBRT: 23.6 $kg \cdot m^{-2}$). Similarly, male BB were leaner than male NBBRT (male BB: 9.8% fat, male NBBRT: 12.9% fat), however no studies presented body composition data for females. None of the papers reported the weight class of BB competitors, and only 7 of 31 studies reported on the use of AAS in their cohorts. This limits the capacity to interpret the range of mass reported and also the variance in mass associated with participation in natural or non-natural competition. The mass and adiposity of the participants in this study were comparable to those reported in a recent systematic review on diet and supplement use in bodybuilding [10], indicating that the physique characteristics of the sample of BB in this review and analysis are consistent with other published literature in this population. Although we identified few studies reporting on elite competitors, the body composition characteristics of this group would be expected to be more extreme. Timing of the body composition measurement is an important consideration for BB competitors, as extreme leanness is reported to be a feature only in the weeks and days immediately before competition [11,13,104,105]. Since phase of competition preparation is an important parameter for interpretation and assessment of body composition characteristics, it is possible that symptoms of MD vary across a competition cycle in conjunction with change in body composition. We identified no studies that had assessed this aspect. Failure to identify phase of training may likely limit the interpretation of MD scores.

Bodybuilders and non-bodybuilders

Of the eight studies comparing BB to non-BB included in this review, six used a resistance trained comparison group (NBBRT). Five of these comparison studies found greater MD symptomatology in BB than in NBBRT, demonstrated by significant ES on most, if not all, subscales of the MD assessment tools used (ES range: 0.03 to 2.35). The meta-analysis combined data from five studies, all of which used the MDI to compare a bodybuilding cohort (361 BB in total) to a resistance trained, non-bodybuilding cohort (368 NBBRT in total). The pooled estimate for each subscale of the MDI showed a medium to large effect of bodybuilding on MD symptoms (ES range: 0.53 to 1.12). Significant heterogeneity was present in the meta-analysis, likely due to the small sample size in some of the included studies, variation in the calibre of participants and variation in levels of engagement in bodybuilding behaviours. However the calculated ES from the studies and the pooled data provide evidence to show MD symptomatology is more prevalent in BB than in NBBRT. When comparing the non-training control participants their scores on the MD tools were generally lower than those of both BB and NBBRT. Overall, the data support that engagement in bodybuilding is associated with a higher risk of characteristics associated with MD. However, it is important to note that this association does not imply causality, and a plausible explanation may posit that those with a predisposition to MD may be attracted to bodybuilding, with participation in bodybuilding, in turn, potentially exacerbating symptoms. For instance, anecdotal reports and ethnographic studies illustrate accounts of those with predispositions towards body image concerns gravitating towards bodybuilding with the purpose of bolstering self-esteem or a sense of masculinity; involvement in bodybuilding gym culture may subsequently exacerbate MD symptomatology [106].

Psychological features

Psychological features associated with MD were examined in 12 of the 31 identified studies. A range of features were investigated, with many often assessed in only a small number of studies. Associated features were similar across both BB and NBBRT. Anxiety, depression, neuroticism and perfectionism were all associated with symptoms of MD, while low self-esteem was associated with greater MD symptoms.

The MD literature has focussed primarily on BB due to the seemingly similar pursuits of BB and those with MD. This has led to a conflation of the two, and often a misrepresentation of bodybuilding as a sport. The psychological features associated with MD identified in this review are not always typical of BB and NBBRT. Frequency and intensity of symptoms of anxiety and social physique anxiety in BB have been found to be lesser than, or comparable to, recreational weight trainers, recreationally active individuals, and non-exercisers [107-109]. Levels of depression are no different in BB than resistance trained and non-resistance trained individuals [54,107,110]. Self-esteem levels in BB have been reported to be higher than [56,108], lower than [110] and no different to [110], active and inactive individuals. These differences in psychological characteristics of BB with and without MD highlight an important difference between the participation in bodybuilding and MD, a difference which previously has not been well defined. These findings suggest that the pursuit of a lean, muscular physique in bodybuilding is not in itself associated with psychological comorbidity; rather it is a non-pathological commitment to an intense training and nutrition plan. When individuals expressing these psychological characteristics take part in this intense program, the potential for developing MD may increase. The evidence to date suggests that although MD symptomatology appears to be higher in BB than NBBRT and non-training controls, BB may not necessarily possess or acquire the psychological features associated with MD such as depression, anxiety and low self-esteem, suggesting that distinct underlying factors underpin the greater MD symptomatology in the bodybuilding samples informing this study. By identifying the psychological characteristics associated with MD in BB and NBBRT, this review better enables clinicians and researchers to differentiate individuals committed to bodybuilding and resistance training activities from individuals who may be suffering from, or at risk of, MD.

Anabolic Androgenic Steroids

Use of AAS has been recognised as a component of MD, and hence has been included in proposed diagnostic criteria [14]. Whether AAS use is a cause or an effect of MD has yet to be determined, however evidence suggests AAS use is a perpetuating factor of MD [111]. Insufficient data were available to calculate effect size in the five studies examining AAS use and MD. The available results are inconsistent regarding comparative rates of MD in AAS users and non-users. Five of the 31 studies compared users to non-users, four of which were in a bodybuilding sample. As expected, the AAS users scored higher than non-users on MDI and MASS subscales related to pharmacological use [51,55]. Other results varied, showing either no difference between users and non-users, or increased symptoms in users. If indeed steroid use is a perpetuating factor in MD, individuals displaying symptoms of MD would likely turn to AAS use to address their perceived lack of size and muscularity. However, higher overall and subscale scores in AAS users suggest that use of appearance and performance enhancing drugs may not be an effective means of reducing other symptoms of MD. The increases in muscle mass and strength associated with AAS use may not reduce the poor self-perception of MD sufferers, only perpetuating the positive feedback loop. Users may continue to perceive their bodies as small, despite the expected gains in muscle mass, thus maintaining or even increasing MD symptoms, and potentially leading to increased AAS usage [111]. Cella, Iannaccone and Cotrufo [86] found that current steroid users did not score lower than former steroid users, which seems to support this assertion. In this study, the use of steroids did not alleviate MD symptoms, and cessation of steroid use did not result in a relapse of MD symptoms, indicating steroid use may not be an effective means of coping with MD.

There were notable limitations of the present analysis. Some of the included studies only crudely defined the BB calibre of participants, and the body composition and training data suggest they were not highly engaged with the sport. Very few studies commented on the training or competition phase of participants, BB were often not described as competitive or non-competitive, and only one study distinguished between training and non-training days. In addition, no longitudinal data were identified. This limits the assessment of how symptomatology may vary over a competition cycle. Longitudinal data may also provide information on how the competitive bodybuilding environment may exacerbate symptoms. Steroid use is common in bodybuilding [70] however 24 of the 31 studies included in the review did not state the drug taking status of participants. There was also a risk of undisclosed steroid use in those studies which did present drug usage information (as this was self-reported). There was a sex bias towards recruitment of male BB and resistance trainers, although this likely mirrors sex participation in competitive bodybuilding. Many of the mixed sex samples grouped the data, rather than separating by sex. More mixed and female samples would better enable insight into differences between males and females in MD. Overall, the quality of the literature informing the study was low to moderate. Further to this, meta-analysis was only able to be conducted on five of the 31 studies and significant heterogeneity was identified. This limits the strength of the evidence. Weaknesses including inadequate assessment of athlete calibre, use of AAS and the influence of competition phase on MD symptoms limit the capacity to evaluate the influence of these factors.

CONCLUSION

This systematic review and meta-analysis supports that BB have greater MD symptomatology than NBBRT. Psychological characteristics associated with MD have been identified in BB and NBBRT. Nevertheless, those with severe MD symptomatology show a greater array of psychiatric comorbidity, including anxiety, depression, perfectionism and low self-esteem, which may be relevant in delineating between pathological and non-pathological muscularity pursuits. We suggest that bodybuilding may attract susceptible individuals, and may also be relevant in cultivating advanced symptomatology in BB with the cluster of psychological features associated with MD. Further evidence is required to definitively elucidate whether bodybuilding is a cause of MD, or whether the sport of bodybuilding attracts those predisposed to MD. Longitudinal studies, controlling for the effect of training and non-training days, would enable measurement of changes in MD symptoms over different stages of bodybuilding preparation and further explicate the nature of the relationship between bodybuilding and MD symptoms.

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CONFLICT OF INTEREST

Lachlan Mitchell, Stuart B. Murray, Stephen Cobley, Daniel Hackett, Janelle Gifford, Louise Capling and Helen O’Connor declare that they have no conflicts of interest directly relevant to the content of this review.

CHAPTER 4.

Correlates of Muscle Dysmorphia Symptomatology in Natural Bodybuilders: Distinguishing Factors in the Pursuit of Hyper-Muscularity

ABSTRACT

Background: Muscle dysmorphia (MD) is characterised by the pathological pursuit of muscularity and leanness, which includes eating- and exercise-related practices. The aim of this cross-sectional study was to identify correlations of MD symptomatology in natural bodybuilders (BB).

Method: An online survey assessing diet, supplementation and training practices, and MD and eating disorder symptoms was completed by male BB with recent experience competing in a drug-tested competition.

Results: Sixty participants (age 29.6 ± 7.1years) completed the survey. Eating disorder scores ($\beta = 0.298$), rate of pre-competition weight loss ($\beta = 0.307$) and number of competitions ($\beta = -0.257$) were significant predictors of MD.

Conclusion: The association between the EAT-26 and MDDI underscores the salience of disordered eating pathology in presentations of MD. Supporting this, greater rate of pre-competition weight loss, which may reflect disordered eating practices, is also associated with MD symptomatology. The inverse association of competition experience suggests novice BB may display increased MD symptomatology.

INTRODUCTION

The ideal male physique is represented by a mesomorphic and lean body [59,60]. Societal expectations relating to this body ideal, and the reward associated with its achievement, drive attempts to increase muscular size and shape through muscularity enhancing pursuits [59]. Similarly, in the context of athletic performance, pressures may relate to both body image and muscularity-oriented pursuits [112]. In pathological extremes, muscle dysmorphia (MD) is thought to encapsulate the disordered pursuit of muscularity, and is most centrally characterized by a distorted self-perception, whereby one believes themselves to be small and weak, often despite well-developed muscularity, and a concomitant pathological drive for muscularity and leanness [14]. Attitudinal and behavioural symptoms echo these characteristics. Meticulous exercise and dietary practices are adhered to, and fastidiously monitored, in aiming to optimise muscular development, while deviation from either food or exercise regimen is associated with marked anxiety [14].

MD is nosologically linked to the eating disorders (ED), and eating practices are known to centrally exacerbate MD symptomatology [113]. Further, pathological exercise practices in MD are known to serve similar emotional regulatory functions to those reported in anorexia nervosa [114]. Perhaps crucially, MD and ED feature weight and shape concern, appearance intolerance, dietary restraint, compulsive exercise, and functional impairment [115], suggesting a broad conceptual similarity, despite symptoms being oriented towards antonymic physique extremes.

Data relating to the elevated risk of ED in some athletic pursuits has been instrumental in shaping preventative efforts [116], although importantly, fewer data exist relating to risk factors for MD. Existing evidence suggests that MD may affect a broad range of athletic groups, including for instance footballers and weightlifters [51]. However, perhaps the greatest implicit overlap between MD and athletic pursuits lies in bodybuilding, where both are oriented towards the pursuit of hypermuscularity and leanness. As with MD, bodybuilding is synonymous with steroid use, although a proportion of bodybuilders (BB) compete in drug-tested federations, where use of performance enhancing drugs is prohibited. Though BB and those afflicted with MD may pursue similar body composition outcomes, a recent systematic review illustrates that engagement in the sport of bodybuilding is not in itself a pathological endeavour [117]. As such, identifying attitudes and behaviours associated with MD symptomatology is of crucial importance [117].

BB typically follow periodised nutrition and training routines to achieve muscular hypertrophy during the off-season, and leanness during the in-season [10]. The meticulous exercise observed in MD has been shown to reflect the training volume of BB [86]. Frequent, longer duration training sessions may highlight the regimen of individuals displaying increased MD symptomatology, a process adopted to target hypermuscularity as well as leanness during competition preparation.

Given the nosological similarities between MD and ED [113-115], borrowing a broader ED framework may be of use in identifying attitudinal and behavioural associations with MD symptomatology. However, few studies have examined potential disordered eating practices in BB, and fewer still have specifically examined this in natural BB. Given the association between steroid use and image-related psychopathology [118], assessing correlates of MD symptomatology in natural BB provides critical evidence of pathological behaviours independent of appearance and performance enhancing substance use. One such behaviour implicated in ED symptomatology is one’s rate of weight loss [119]. In a bodybuilding context, a rapid loss of weight during the in-season period, indicated by greater weight loss per week of preparation, may reflect an intolerance towards maintaining a reduced weight, and thus symptomatic behaviour. As such, a rapid weight loss leading to competition may delay and limit the period of time spent at a reduced body weight, and may act to reduce the noted anxiety associated with reduced muscularity.

Addressing this gap, the present study aimed to identify correlates of MD symptomatology in natural BB, which would provide crucial data relevant in deconstructing the inference that bodybuilding and symptoms of MD are synonymous. In light of existing evidence, we hypothesized that ED symptoms would be associated with MD symptomatology, but not a non-pathological pursuit of muscularity (i.e., bodybuilding).

METHODS

Participants

Participants were male, aged 18 years or over, and had competed in at least one natural bodybuilding contest within the previous 18 months. Participants were recruited through distribution of the survey link online via social media, and at the Australasian Natural Bodybuilding national titles in October 2015, as part of a broader ongoing study in natural BB. Ethics approval was obtained from the University of Sydney Human Ethics Committee (project 2015/732). Informed consent was obtained on entry to the survey, which was open between October 2015-September 2016.

A total of 319 individuals logged onto the survey. Of these, 178 failed to meet inclusion criteria and therefore did not progress to question 1. A further 42 met inclusion however failed to complete > 25% of survey items and were excluded from analysis. All remaining 99 participants completed the survey, however 39 of these failed to meet study inclusion criteria, leaving 60 (60.6% of completers) participants included in the analysis. Reasons for exclusion at this latter point were not competing in the bodybuilding category (28/39 completers), no recent competition experience (10/39 completers), and competing in a non-drug tested competition (1/39 completers). Demographic characteristics of included participants are presented in Table 4.1.

Survey items

Participant training routine and demographics, including highest historical weight, competition weight, in-season duration, and bodybuilding history, were assessed using an adapted version of a self-report questionnaire that our group previously developed [9].

The Muscle Dysmorphic Disorder Inventory (MDDI) [120] is a 13-item questionnaire measure of MD symptomatology that comprises 3 subscales; drive for size, appearance intolerance, and functional impairment. Total scores range from 13 to 65, with higher scores reflecting greater MD psychopathology. The MDDI was selected to assess MD symptoms as it encompasses the perceptual, cognitive, emotional and behavioural disturbances related to the desire to be more lean and muscular apparent in MD. As such, the subscales of the MDDI provide measurements of the thoughts, feelings and behaviours related to MD, and hence predict these three separate constructs of MD [120]. Therefore this tool is consistent with the multidimensional definition of body image disturbance in MD [120]. The questionnaire is not a diagnostic tool but has been widely used to identify individuals displaying symptoms associated with MD [17,50,85]. The MDDI yields good psychometric properties, with test-retest reliability previously reported to range from 0.81 to 0.87 [120]. In the present study, internal consistency was acceptable (α = 0.81).

The Eating Attitudes Test 26-Items (EAT-26) [121] is a self-report questionnaire assessing disordered eating symptoms. Total scores range from 0 to 78, with higher scores indicating increased ED psychopathology. The EAT-26 contains three subscales: dieting, bulimia and food preoccupation, and oral control. Consistent with previous research relating to ED attitudes and cognitions, behavioural questions additional to the 26 items were not added to the EAT-26 in the present study [122,123]. The EAT-26 was selected due to its accuracy in self-reported testing of non-clinical populations [122], and its previous use in assessing disordered eating symptoms in resistance trained men [99]. While not a diagnostic tool, a score of 20 or above indicates a high level of concern about dieting, body weight, and problematic behaviours. The EAT-26 demonstrates good psychometric properties, and in the present study, acceptable internal consistency was noted (α = 0.78).

Analysis

Mean and standard deviation scores were calculated for demographic and assessment instrument (MDDI, EAT-26) data. Weight suppression was calculated as highest historical weight minus reported competition weight. A rate of weight loss, defined as the average number of kilograms of body mass lost per week during the in-season, was calculated as a function of weight suppression divided by in-season duration. Training volume was calculated as a product of number of training sessions per week and training session duration.

Pearson's correlations were calculated to investigate interrelationships between MDDI and survey variables. Simultaneous multiple linear regression analysis was performed to further investigate the relationship between MDDI total score and survey variables. Based on the hypotheses, correlation outcomes, and symptoms of MD, EAT-26 total score, total in-season training volume, rate of weight loss, and number of competitions were set as independent variables. The standardised residual versus fitted values plot suggested the fitted model was adequate and the normal probability plot of standardised residuals suggested the normality assumption held so valid inferences can be made. Analyses were conducted using IBM SPSS statistics version 22 (IBM SPSS; Chicago, Illinois). Significance was set at $p < 0.05$.

RESULTS

Mean scores for the EAT-26 were low (8.5 ± 6.3), while mean scores for the MDDI were moderate (35.2 ± 8.0), although scores for both scales ranged widely (1-32 and 15-55, respectively). Five participants scored at or above 20 on the EAT-26 (Table 4.1). There were significant correlations between MDDI total score and EAT-26 total score ($r = 0.31$, $p < 0.05$), weight suppression ($r = 0.259$, $p < 0.05$), rate of weight loss ($r = 0.297$, $p < 0.05$), and number of contests completed ($r = -0.32$, $p < 0.05$).

The multiple regression considering the dependent variable MDDI total score and the independent variables EAT-26 total score, in-season training volume, rate of weight loss, and number of competitions, reached significance (F (4, 54) = 4.819, $p < 0.01$). The model included EAT-26 total score (β = 0.298), rate of weight loss (β = 0.307), and number of competitions (β = -0.257). There was no association between MDDI total score and in-season training volume. The adjusted R^2 of the model with the three included variables was 0.208 (Table 4.2).

Table 4.1. Demographic characteristics, training volume, EAT-26 and MDDI results of participants (*n* = 60)

	Mean ± *SD*	95% *C.I.*	Range
Age (years)	29.6 ± 7.1	27.6 - 31.1	19-55
Current weight (kg)	85.0 ± 11.4	81.9 - 87.8	62-122
Current BMI (kg/m^2)	27.5 ± 3.6	26.6 - 28.4	23-42
Highest weight (kg)	90.0 ± 11.5	87.6 - 93.45	66-132
Competition weight (kg)	75.8 ± 8.5	76.7 - 78.2	55-106
Years bodybuilding (years)	3.7 ± 3.2	2.8 - 4.5	1-15
Number of contests	4.0 ± 3.9	3.1 - 4.9	1-15
In-season duration (weeks)	23.0 ± 9.0	20.8 - 25.4	12-50
Off-season training volume (mins/week)	351.9 ± 57.8	337-9 - 367.1	240-480
In-season training volume (mins/week)	487.1 ± 117.8	458.7 - 515.8	285-900
EAT-26	8.5 ± 6.3	7.0 - 10.1	1-32
MDDI	35.2 ± 8.0	33.3 - 37.4	15-55

BMI, body mass index; EAT-26, Eating Attitudes Test 26-Items; MDDI, Muscle Dysmorphic Disorder Inventory; *SD*, standard deviation; *C.I.*, confidence interval.

Table 4.2. Explanatory variables of the MDDI total score (simultaneous multiple linear regression)

Independent variable	β	*p*
EAT-26	0.298	0.018
Rate of weight loss	0.307	0.012
Total in-season training volume	-0.102	0.393
Number of competitions	-0.257	0.04
Adjusted R^2	0.208	

EAT-26, Eating Attitudes Test 26-Items

DISCUSSION

Main findings

The purpose of the present study was to identify correlates of MD symptomatology within a sample of those pursuing a hyper-muscular body without the use of performance enhancing drugs, specifically, competitive natural BB. In light of evidence suggesting an overlap between ED symptomatology and MD psychopathology [81], our primary aims were to assess the associations between disordered eating attitudes and behaviours and MD symptoms in competitive, male, natural BB. A key finding of this study was the significant and positive association of ED pathology with MD symptomatology, supporting the thesis that MD symptomatology may include pathological eating attitudes and behaviours [81]. Interestingly, our results also revealed that the rapidity of weight loss during competition preparation was associated with MD symptoms, while conversely, no association was found between training volume and MDDI. The wide range of MDDI scores reported in this sample supports previous research which indicates that participation in bodybuilding does not in itself infer MD; rather, a proportion of participants may display increased MD symptomatology [117].

Muscle dysmorphia and eating disorder psychopathology

The moderate but wide range in MDDI scores in this sample (35.2 ± 8.0, 15-55) is comparable to a sample of 60 competitive BB (38.5 ± 8.0), higher than 60 non-competitive BB (29.6 ± 6.6) [50], and relatively higher than 25 BB and 126 resistance trained non-bodybuilders assessed using a 21 item MDDI (45.5 ± 12.5, 45.9 ± 12.4, respectively) [85].

The notion that disordered eating psychopathology was found to be significantly associated with MD symptomatology in this sample of competitive natural BB yields significant implications. This result supports our hypothesis, and extends previous research that identified correlations between disordered eating and MD in resistance trained samples [81], ultimately underscoring the salience of disordered eating pathology in presentations of MD symptomatology. Although steroid use has been accepted as an indicator for drive for muscularity and MD, natural BB have previously demonstrated similar MD symptomatology to non-natural BB [51]. The association found between EAT-26 and MDDI in this natural sample indicates those BB less likely to adopt pharmacological practices in the pursuit of muscularity may still be at risk of other pathological behaviours. Further, our results also suggest that the intensive nutritional regimens employed by BB may not in themselves indicate psychopathology, but rather, it is when the eating behaviours become disordered that MD symptomatology may increase. Further research is required to examine this speculation. Given that ED symptomatology temporally fluctuates over time dependent on the degree of engagement in safety- and symptomatic-behaviours [124], disordered eating behaviours associated with MD would likely fluctuate too. This fluctuation would suggest the severity of MD symptomatology may vary in association with this ED variability, as well as training and competition status [17].

Rate of weight loss

This is the first study to examine associations between rate of weight loss and symptoms of MD. The rate at which participants reduced their body weight during competition preparation showed the highest association with MD symptomatology. This may reflect, among BB experiencing MD, an intolerance towards maintaining a lower body weight, due to the noted fear of loss of muscularity [113]. If so, rather than taking a titrated approach to weight loss during competition preparation, a rapid reduction in weight may assuage distress associated with reduced muscular size by minimizing the period of reduced weight. The rapid reduction in weight is likely mediated by significant dietary restraint, further underscoring the pathological nature of this weight loss, and the potential link between MD and ED symptomatology. The association of rate of weight loss suggests that what may differentiate BB displaying increased MD symptomatology is the time period committed to achieve their weight loss. A rapid transition between the extremes of size and leanness may be desired by those expressing greater MD symptomatology.

Competition experience

Competition experience was inversely associated with MD symptomatology, suggesting participants who had competed fewer times scored higher on the MDDI. This result opposes those found in a previous study, which demonstrated no difference in MD symptoms between experienced and novice female BB [48]. Gender-related aspects may moderate the associations found in this study, therefore female muscularity concerns and bodybuilding require additional investigation. One possible explanation for this inverse association is that individuals susceptible to, or already exhibiting features of MD, are drawn to the sport of bodybuilding in hopes of appeasing symptoms. However, their cognitive and behavioral symptoms may impede longer-term engagement in the sport, thus they discontinue competing. An alternative explanation may be that MD symptoms are reduced as BB continue participation in the sport, suggesting longer-term engagement in bodybuilding may help to alleviate MD behaviours.

The limitations of this study include a modest sample size (n = 60) which requires consideration when interpreting the non-significant findings. A larger sample would have increased statistical power to assess the association of the non-significant findings. The online, self-report nature of the survey may preclude a confirmation of all participants meeting the specific competitive bodybuilding inclusion criteria. Finally, a cross-sectional study design was employed and data were not collected at a standardised time point during competition preparation. Symptoms of MD may vary based on preparation phase and proximity of competition.

CONCLUSION

In conclusion, this study identified unique associations between ED psychopathology, rate of weight loss, and bodybuilding experience, and MD symptomatology in a sample of male natural BB. Longitudinal studies are vital to assess fluctuations in MD and ED symptoms during competition preparation, and to directly assess the association between rate of weight loss and MD symptomatology.

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CONFLICT OF INTEREST

HOC receives payments from Sports Dietitians Australia for professional presentations delivered in a continuing education course for Sports Dietitians. All other authors declare no competing or conflicts of interest.

CHAPTER 5.

Do Bodybuilders Use Evidence Based Nutrition Strategies to Manipulate Physique?

ABSTRACT

Background: Competitive bodybuilders (BB) undergo strict dietary and training practices to achieve an extremely lean and muscular physique. The purpose of this study was to identify and describe different dietary strategies used by BB, their rationale, and the sources of information from which these strategies are gathered.

Method: In-depth interviews were conducted with seven experienced (10.4 ± 3.4 years bodybuilding experience), male, natural BB. Participants were asked about training, dietary and supplement practices, and information resources for bodybuilding strategies. Interviews were transcribed verbatim and analysed using qualitative content analysis.

Results: During the off-season, energy intake was higher and less restricted than during the in-season to aid in muscle hypertrophy. There was a focus on high protein intake with adequate carbohydrate to permit high training loads. To create an energy deficit and loss of fat mass, energy intake was gradually and progressively reduced during the in-season via a reduction in carbohydrate and fat intake. The rationale for weekly higher carbohydrate re-feed days was to off-set declines in metabolic rate and fatigue, while in the final “peak week” before competition, the reasoning for fluid and sodium manipulation and carbohydrate loading was to enhance the appearance of leanness and vascularity. Other BB, coaches and the internet were significant sources of information.

Conclusion: Despite the common perception of extreme, non-evidence based regimens, these BB reported predominantly using strategies which are recognised as evidence based, developed over many years of experience. Additionally, novel strategies such as weekly re-feed days to enhance

fat loss, and sodium and fluid manipulation, warrant further investigation to evaluate their efficacy and safety.

INTRODUCTION

Competitive bodybuilders (BB) undergo strict dietary and training practices to achieve an extremely lean, muscular and symmetrical physique [10]. Along with resistance and aerobic exercise [9], targeted energy and macronutrient intakes are followed to accumulate muscle mass in the off-season, and reduce fat mass in the in-season [10]. However the specific dietary strategies employed by BB and their underpinning rationale remain poorly understood.

Contemporary literature examining the dietary intakes of BB is limited [10], and given the unique nature of competitive bodybuilding, it may be inappropriate to draw dietary parallels from other sports. Although BB have been reported to follow extreme, non-evidence based approaches, several dietary strategies developed in bodybuilding have recently been scientifically validated, such as frequent dosing of protein [2], and intake of protein around training [3]. Identifying the dietary strategies of modern BB, and exploring their underpinning rationale, will provide exercise, sport and nutrition practitioners with an understanding of current bodybuilding methods and insights to assist with negotiating practical and effective ways to work towards bodybuilding goals. Furthermore, identifying such strategies will also generate hypotheses for future research.

In-depth interviews allow a deep exploration of the discussed topic, enable the researchers to enter new areas and produce rich data, with an additional benefit of uncovering practices that had not been anticipated [125,126]. The purpose of this study was to use in-depth interviews to identify and describe different dietary strategies used by male, natural BB, their rationale, and the sources of education from which these strategies are gathered.

METHODS

Participants were purposively selected by the research team based on expertise and experience in competitive bodybuilding. To recruit participants, experienced BB known to the researchers from previous studies were invited to participate. Adverts were placed on the website and social media page of Australasian Natural Bodybuilding, and distributed at the Australasian Natural Bodybuilding national titles in October 2015. To be included, participants needed to be male, natural (drug-free) BB, aged 18 years and older, with five or more years of bodybuilding experience. Participants were required to have competed in the bodybuilding category at national or international level contests of drug-tested federations.

Table 5.1. Individual participant characteristics of seven experienced male, natural bodybuilders participating in in-depth interviews

Participant	Age (years)	Years of bodybuilding	Number of competitions	Competition category	Level of competition and competition success
Oliver	43	8	15	Masters; weight category	National (fourth place)
Luke	40	17	15	Opens; weight category	International (winner); Pro card
Kyle	25	7	15	Opens; weight category	International (winner); Pro card
Keith	22	7	8	Teenage; junior	National (winner)
Ben	30	13	12	Opens; weight category	National (fourth place)
Harry	32	10	9	Opens; weight category	State (winner); Pro card
Will	65	11	26	Grand masters; ultra-grand masters	International (winner)

Masters, >40 years; Teenage, <19 years; Junior, 19-22 years; Grand masters, >50 years; Ultra-grand masters, >60 years

Procedures

The interviews were conducted by three members of the research team between March 2015 and February 2016. Interviews (78-124 minutes) were held by telephone or Skype. The combined duration of all interviews was 11 hours. Interviews captured participant demographic characteristics including age, years of bodybuilding experience, number of previous competitions, and competition success. Participants were asked about their training, dietary, supplement and competition preparation practices, the rationale behind these practices, and where they obtained information about nutrition and training. By the end of the last interview, no new major themes were emerging. Saturation was confirmed following coding of the data, therefore the decision was made to cease further data collection.

Analysis

All interviews were digitally recorded and transcribed by a commercial transcription service (waywithwords.com). Transcripts were returned to participants for verification and correction to ensure the transcription correctly reflected the content of their interview. One participant returned the transcript with minor emendations which was included in the analysis. Notes were taken during all interviews and used to clarify transcription errors, and to confirm the meaning of spoken phrases during the coding process. To protect the identity of the participants a pseudonym was used in the final transcripts. All interviews were conducted prior to thematic analysis via qualitative content analysis using qualitative data analysis software (NVivo version 10.0, QSR International PTY Ltd., Doncaster, Australia, 2012). Coding was undertaken by one researcher (LM) with assistance from a second (FE) and overseen by a third researcher experienced in qualitative research (JG), who reviewed any queries. As coding of data proceeded, underlying themes emerged as participants discussed topics introduced by the interviewers, and was not constrained by the original structure of the interview. Identification of themes recurring through and across interviews was achieved through a process of reading, coding, code category refinement, rereading and code checking, and analysis of developing concepts. A coding journal with an audit trail of changes in coding and code refinement was maintained by the primary coder (LM) to maintain transparency of the qualitative analysis process.

Counts of coded talk were available from the analysis software by grouping for diet, training, supplements, and information and education. Counts within themes could have more than one section of speech by the same participant. To avoid researcher bias during the data interpretation process based on pre-conceived ideas of bodybuilding practices, identified themes were sent to participants, who confirmed correct interpretation.

Ethical approval was received from the University of Sydney Human Ethics Committee, project number 2014/968. Written informed consent was provided by all participants. Participation was voluntary and identity of participants and confidentiality of their responses was ensured.

RESULTS

A total of seven BB (10.4 ± 3.4 years bodybuilding experience) meeting inclusion criteria responded to advertisements and consented to participate. Participant characteristics are summarised in Table 5.1. Four participants had competed at national, and three at international level. Two participants had competed professionally, with an additional one participant eligible to compete professionally. Example quotes are presented in Table 5.2. Selected quotes were representative of themes identified during interviews.

Diet

Off-season

All participants consumed four to six meals per day, with a targeted energy and macro nutrient intake aimed to support muscular hypertrophy, "I've got 250 [g/day] protein, and at the moment I'll divvy my fats and carbs up, so 250 [g] protein, 680 [g] carb and about 100, 110 [g] on fats, somewhere there," (Keith). Each meal featured a large serving of a high protein food and a large serving of vegetables, "In the morning I start off with 100 grams of oats and six whole eggs. That's at around about 7:00 am. At 9:30 am will be 200 grams of salmon and 200 grams of green veg," (Luke). The off-season diet contained a wide variety of foods, including processed foods such as ice cream, and was less regimented than the in-season.

In-season

While the pattern and style of the diet was similar to the off-season, the in-season intake was more structured, "It's more structured, it's perfect" (Kyle), and usually carefully measured, "I will split a grain of rice, if it made it hit exactly the grammage (sic) I want," (Keith). Serving sizes were also reduced as competition approached.

Progressive reductions in carbohydrate and fat intake were used to create then maintain an energy deficit to elicit fat loss (Figure 5.1). Protein intake remained similar to the off-season to prevent loss of lean mass. Carbohydrate intake was carefully timed around exercise (pre-, during and post-training) to ensure training was optimised.

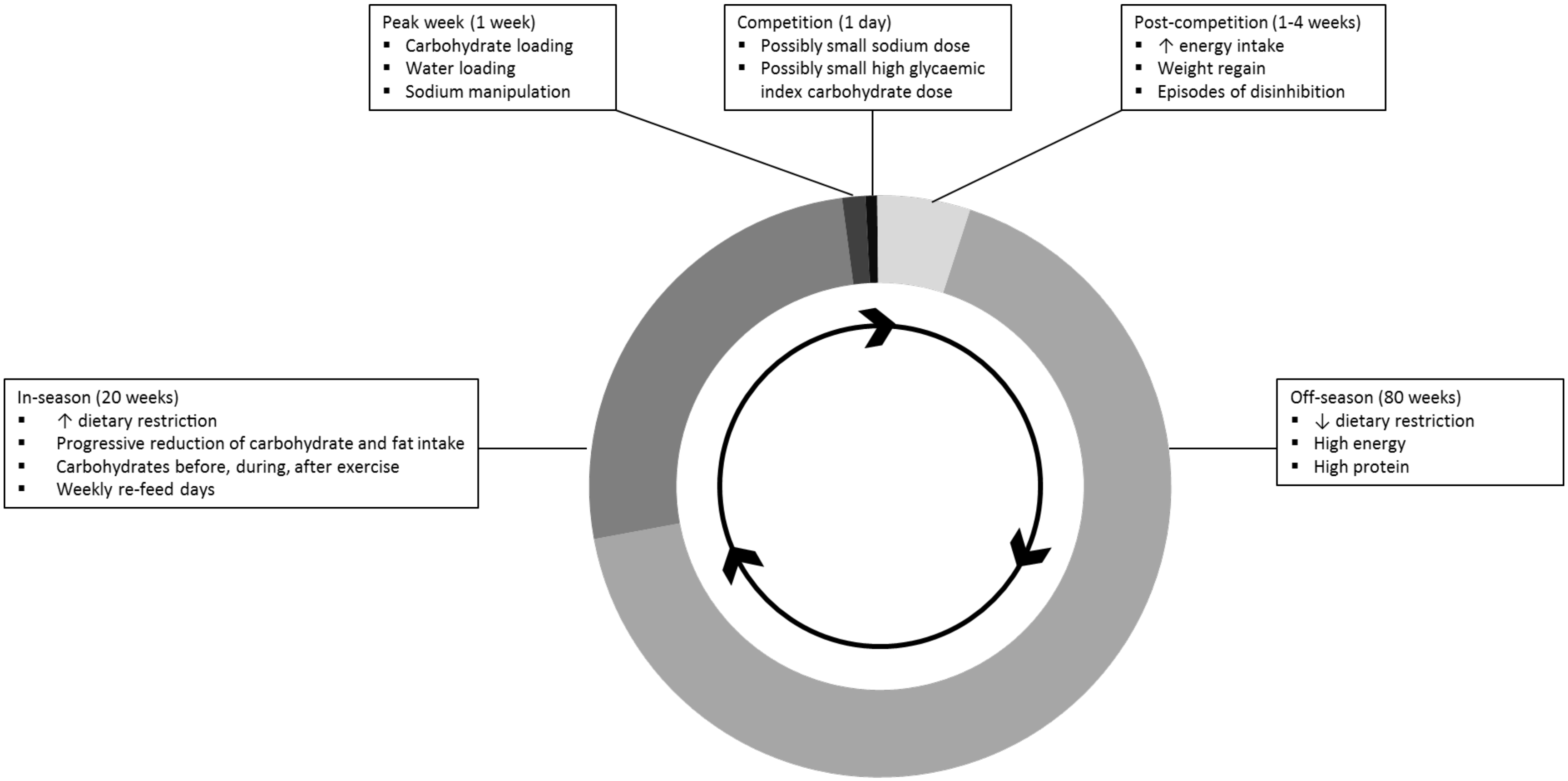

Figure 5.1. Doughnut chart representation of the stages of bodybuilding preparation, including key dietary strategies used, as reported by seven experienced male, competitive natural bodybuilders participating in in-depth interviews. Duration of stages are approximate and vary between bodybuilders.

Re-feed days

Re-feed days were commonly used during the in-season and primarily aimed to increase energy intake through elevated carbohydrate consumption. Participants discussed positive outcomes including increased glycogen stores which aid training performance, mental recovery, and prevention of further adaptive downgrades in energy expenditure, stimulating weight loss. One participant described it as a “metabolic jumpstart” (Oliver). Compared to preparations without re-feed days, participants discussed consuming more total energy, over a shorter preparation, achieving better fat loss and muscle retention using weekly re-feed days.

Peak week

The week prior to the contest was defined as a “peak week” where particular short-term strategies were used to achieve the leanest possible appearance. Six participants used a modified carbohydrate loading regimen (tapered training and increased carbohydrate intake) [127] in order to increase glycogen and theoretically increase muscle volume. Four participants had previously used the classic loading method, which involved a three day glycogen depletion and then super-compensation [128], however found this did not produce significant changes in appearance, describing this method as, “stressful,” (Ben) “mentally that would be really bad,” (Kyle) and, “you’re just a wreck” (Luke).

All seven participants discussed the practice of water loading and cutting during peak week. Users of this strategy consumed more than 10 litres of water per day early in the week, then reduced water intake each day leading into the contest. The rationale for this strategy was to increase fluid excretion and to “go after subcutaneous water” (Will), which would purportedly provide a leaner, more vascular appearance. Results were not effective enough for these participants to warrant continuation of this strategy in subsequent competition preparations. Other participants commented that the idea of water loading and cutting does not make sense physiologically: "muscle is about 70% water. If you were dehydrated, the muscles are going to look smaller as well," (Harry).

Sodium manipulation was another strategy used during the peak week to reduce body water and produce a leaner appearance. Three participants discussed previously using this strategy, whereby sodium intake was greatly increased for three days, followed by a complete restriction of salt for three days. However, they each reported that the results were inconsistent, and discontinued the strategy.

Competition day

Six participants discussed diet strategies used on the day of competition. Two consumed sodium prior to posing on stage to get a greater "pump". Small doses of high glycaemic index carbohydrates were consumed by two participants. One justified this by saying, "That was just to keep you ticking, when you're feeling that depleted, just to keep you propped up," (Oliver) while the other participant commented, "That's for sugars, to get the pump" (Kyle). Two participants did not change from their usual intake on competition day.

Post-competition

Participants reported the post-competition diet was more relaxed ($n = 5$), and included some "treat" foods not consumed during the in-season. Overindulgence and the experience of feeling physically sick from the change in diet pattern ($n = 2$) was reported. Weight regain was common and could be substantial (8-10 kg over three weeks in one case). Limited time off dieting was reported by three participants to avoid detrimental physique changes. Participants reported negative changes in physique were common post-competition.

Table 5.2. Thematic summary of dietary practices and sources of dietary education, in seven experienced male, competitive natural bodybuilders participating in in-depth interviews.

Themes	**Subthemes**	**Number of references**	**Indicative quotes**
Off-season			
	Meals	47	"Lunch would be, again, probably a 200 gram chicken breast, one cooked cup of brown rice and maybe about 100 grams of green veggies… Meal four, which is afternoon tea, which, prior to gym, is exactly the same as the meal before, the lunch meal, so the chicken, rice, veggie one, then after gym, which would be dinner, would be usually a meat, a red meat, so a steak, maybe a 200 gram, you know, rump steak, another cooked cup of brown rice and some veggies, and that's dinner." (Luke) "I have a dose of protein and carbohydrate with each meal…for protein I usually cycle between a few different sources. I use whey protein, and then of course the one that is salmon, white flesh fish, kangaroo and beef, they're going to be my primary, I'll cycle between those different protein sources" (Keith)
	Carbohydrates	6	"I dose my carbohydrate really high, because I want to make sure that my glucose metabolism is the best it possibly can be, because I will always diet on a high carbohydrate template to keep my training intensity high." (Keith)
	Protein	3	"Anywhere from 2.2 to 2.9 grams per kilo body weight. That's not total lean mass but just my total body weight." (Keith)
	Fat	3	"I will direct my fat anywhere from 0.5 to a maximum 1.2 grams per kilo, so I keep my fats relatively moderate." (Keith)

	Energy	3	"So I might sit at anywhere from, I used to sit at between 4500 and 5000 calories [per day] in my off season." (Keith)
In-season			
	Meals	34	"Each meal, just to start cutting the calories a little bit. The egg yolks would go from the eggs at night, just down to egg white, just, again, to start cutting some calories, and they would slowly go down, so in four eggs would go only three yolks. And then a couple of weeks later it'll be down to two yolks and then one yolk." (Luke)
	Carbohydrates	16	"The carb value will slowly come down. Around training, it's going to remain quite high and in the morning it's high-ish. But, yes, the carb value will slowly come down." (Kyle)
			"Usually I make a drop, and I will either dig from fats, or carbs, or a combination of. I'm generally in favor of dropping carbohydrates initially and then digging into fats later," (Keith)
			"I don't have an issue with energy when I have my carbs around my training time, so pre-, intra- and post-workout is when I consume the majority of my carbohydrates through the day," (Luke)
			"I will actually introduce more carbohydrate for fuel, you know, to fuel the requirement to get through, say, a 35-minute interval session," (Oliver)
	Protein	7	"I normally keep protein static. I'll set it slightly higher than the off-season at the start of my prep and then just keep it the same throughout even if I lose weight. So if you were to look at it from a gram per kilogram basis, it would look like it's going up, but it's the same gram amount. So I'll start at 225 grams protein and just keep that throughout, so that will be roughly like 2.3, 2.4 grams per kg," (Harry)
	Fat	7	"I think I start with my fat probably around 25% [of energy] and then it might get as low as 15% to 20% at the end… So a day at the very end might be 40 grams of fat." (Harry)

			"So for example, I might start [the in-season] with my fat around 65 grams [per day] and then that will only get decreased by maximum of 25 grams while the carbohydrates can drop from, you know, 250 [g] at the start or 275 [g] all the way down to 100 [g] at the end on my low days," (Harry)
	Energy	15	"So I probably start on average about 2400-2500 calories [per day] across the seven days, and I probably finish around 2000 or 1900 [per day] with probably a two-fold increase in cardio." (Harry)
Refeed days			
	Refeed days	32	"I have one day that's closer to my, like my off-season calories. So that might be like 2800 calories on a day predominantly increasing carbohydrate. That's to kind of stimulate further losses to prevent some of the downgrades in my energy expenditure you could say, and to replenish glycogen, to feel mentally refreshed, to get a break in." (Harry)
Peak week			
	Carbohydrate loading	39	"So normally, I will increase my carbohydrates early in the week, sometime around Tuesday or Wednesday for Saturday show, taper them back down but not all the way down where they were at the lowest low. So maybe 400 [grams] for a day and then down to say 350 [g/d], 300 [g/d], 250 [g/d], and then on Friday and Saturday, the show, I will be closer to 300 or the 400 [g/d] range to kind of fill back out. So it's basically kind of like a modified carb loading strategy an endurance athlete would use." (Harry) "The idea is to, you know, wring out the sponge, I suppose, of the last stage of leaning out in those depletion days, and they would be paired with high volume gym work, and the theory behind it was, apparently, to swell the muscle belly, it's not a vascular thing, it was actually just increased overall fullness of the muscle once you flooded it with carbohydrate." (Oliver)

			"He felt I looked my best, you know, 24 hours prior to the competition, so all these little things you've sort of got to take note of and you think, all right, I look this good now, it'll be even better tomorrow, and in my case it wasn't, and you think, well, maybe we just do a carb load of two days next time around instead of three, if that works perfectly for that timeframe." (Oliver)
	Water loading	17	"So then the water is still going in around about ten litres a day… then the water would start to, the water would start to cut back again as well and that was, sort of, you know, Thursday might still be up around about the ten litres, but then Friday and Saturday, Friday might cut down to around about four litres and then Saturday was two litres prior to, sort of, two o'clock or something like that… And then, you know, nothing, yes." (Luke)
			"Muscle is 70% water and I'm not aware of any mechanism that tells the body to go after subcutaneous water. If you're going to dehydrate, it's going to be from everywhere and why are you pulling 70, you know, why are you pulling so much volume out of your muscles because you're really wanting your muscles to be volumised?" (Will)
			"Those things don't work for me," (Ben)
			"A terrible, terrible thing to put your body through," (Luke)
	Sodium manipulation	12	"So on the Monday, Tuesday, Wednesday would be salt in each meal, with probably around about two grams of salt, a gram, yes, one or two grams of salt with each meal, which was great, but then by Wednesday, oh man, you've just had this salty fishy chicken meal, it's just absolutely disgusting and terrible. And then on the Thursday, Friday, Saturday, the salt would be dropped out." (Luke)
			"It's such a variable which can be really, really… Completely screw you up… Like, if you diet for 16 weeks and then the last two days you mess around with your sodium, and then you come on the stage bloated, it's such a… It's such a bummer." (Kyle)

Post-competition			
	Post-competition	15	"You kind of work yourself up into a frenzy," (Ben) "It's not so much hunger, it's more so flavour. It's more sort of like I want a pizza because I haven't had it in months," (Kyle) "We eat everything we haven't eaten all year," (Will)
Supplements			
	Protein powders	23	"I take, obviously, protein powders. I take WPI [whey protein isolate] just because it's, you know, it's fast to absorb, or whatever… And then obviously, yes, and then obviously casein at night." (Kyle)
	Creatine	15	"I don't think I've stopped taking creatine monohydrate since 2004 to be honest." (Harry) "The only thing I ever saw a result from was Creatine. My wife would always say, 'You've started using that Creatine again, haven't you?' I'd say, 'Why?' She'd say, 'Oh, you've got that swollen look about you, you know, that volumised look.'" (Will)
	Glutamine	10	"Glutamine is ten grams post training in the off-season. Once I'm in diet mode for comp, especially the last four or five weeks, I up that to around about 40 grams a day." (Luke) "It's supposed to help with your immune system and anti-catabolic, so being on a lower calorie diet, I'm trying to stop muscle catabolism and Glutamine is supposed to help out. And the last three times that I've dieted, I've, before that, the last four weeks I used to always get sick, always catch a cold or something. The last three times I've dieted, I've upped, had 40 grams of Glutamine a day for the last four or five weeks and I haven't gotten sick." (Luke)
	Pre-workouts	9	"And it worked really well. It was, I was really focused in the gym… I just wanted to keep on training. I was just thinking about training, thinking about what I was doing at that time and was getting really into, into that workout." (Luke)

			"I'm quite sensitive to caffeine by itself and I've had some of those pre-workouts and not gotten to sleep until one or two o'clock in the morning and that's having had it at 4:30 in the afternoon, five o'clock in the afternoon. So I've actually stayed away from those because of that." (Luke)
Sources of education			
	Other bodybuilders	15	"He's just been competing for, I don't know, like, a lot of years, so, yes. He kind of, he is the guy who I'll run everything by him. If I have an idea, like, should I do this maybe with my, you know, carbs, or whatever, I'll run it by him first and he'll give the okay or he'll say, maybe just try this." (Kyle) "They might have good body parts and, you know, if you get your legs looking like that or your back looking like that and you see what sport they've come from or what type of training they do for that body part, but then again, it may just come down to a genetic predisposition for that particular body part." (Luke)
	Internet	15	"When I first got into it, I was not nearly as versed in the, I guess, the empirical evidence kind of way of thinking. I was reading posts online, bodybuilding.com forums. I was a regular on it." (Harry) "Just Googling, you know, bodybuilding, you'll get a… you will get some good information but you… they don't necessarily know what is good and what's bad." (Harry) "The internet's going to be everyone's first port of call," (Kyle) "The internet is littered with online gurus," (Oliver) "It then just comes back to social media, and it's the problem what I call the good-looking trainer. So the most popular ones with the most likes, whatever, let's face it, they're the good-looking blokes or the good-looking girls, most of which, unfortunately, don't have that much between their ears but they have a huge following because most of their posts they've got

		their shirt off or they walk around in a bikini and everyone thinks they look great, so whatever they're about to tell you must be good, rather than some rough-headed coach who's in his 60s who's done this sort of stuff all his life," (Oliver) "He's 17 years old and he's following all these guys on Instagram and Facebook and things like that, and I don't think they know. I've told him, 'Mate, he's not natural. Sure, have that as an attainable goal in your mind. If you fall short of that, you're still going to be looking great.' But I said, 'Be under no illusion that that is natural,' so I think a lot of the guys don't know. They're naive to it," (Luke)
Science and evidence based sources	7	"I did very quickly gravitate towards more what I perceived to be more science-based and evidence-based approaches rather than just what were the big guys doing. To me, it was relatively intuitive that some genetic freak on a butt load of steroids and what worked for him would probably not be the same thing as what works for a more or less average bodybuilder who wasn't going to be taking drugs." (Harry)
Coaches	6	"There's not a whole lot of open information and sort of themes it's just passed down from coaches in a tradition… I suppose I learn the majority of what I do through coaches and colleagues I worked with over time." (Keith) "There are also a lot of "coaches" out there who don't, who are the same as them, you know. Most people, they compete in one or two shows and, you know, read a few magazine articles and they think they know how to be a coach. So the average coach is not a… the average coach doesn't even have a bachelor degree to be honest." (Harry)

Supplements

All participants used one or more dietary supplements. In total, 18 different supplement types were mentioned. Creatine (3-15 g/d) was used by all participants with doses consumed either pre- or post-workout, with a meal, or a combination of these. Protein powders were also used by all participants either as a post-training supplement (n = 4) or as a source of protein during meals (n = 4). “Pre-workout” supplements designed to stimulate enhanced training was discussed by four participants, one of which used these for their caffeine content, while the others discontinued use due to side effects (insomnia, increased and variable heart rate, and increased respiratory rate). Participants reported these experiences were: “absolutely horrible” (Ben), “I just can’t stand it, frankly,” (Will) and “it’s counter-productive, so I don’t use it” (Will). Other supplements more commonly used were fish oil (four participants), glutamine (three participants) and testosterone boosters (three participants).

Sources of education

The most commonly reported sources of education were the internet including bodybuilding and strength and conditioning websites and forums (n = 5), successful BB (n = 4), and bodybuilding coaches (n = 4). The quality of information available on the internet was considered to be both reputable and non-reputable. Concerns were raised by two participants regarding information on social media, where images and information may be unrealistic and deceptive, and potentially damaging for novices. Bodybuilding coaches were also commonly used, although one participant commented on the varying levels of coach knowledge, with many relying on their own competition experience.

DISCUSSION

The rationale and use of several key dietary strategies emerged from this study, including regular doses of protein throughout the day to maximise accrual and maintenance of lean mass, and utilising carbohydrate foods as a fuel source pre-, during and post-exercise. Weekly re-feed days were implemented during the in-season, to provide both a psychological rest and reportedly assist with fat loss. During the peak week BB followed extreme strategies including water and sodium manipulation in an attempt to achieve the leanest physique.

Throughout both the off-season and in-season, participants reported consuming large, frequent servings of protein to build and maintain muscle mass, which is empirically supported in the research literature [2]. The optimal dose to achieve this maximal muscle protein synthesis is accepted to be 20-30 g of high quality protein [2,129], with studies supporting that protein ingestion above this dose is oxidised [129]. Recent findings suggest the amount of muscle mass trained may be a determinant of protein requirements post-exercise. Greater myofibrillar fractional synthetic rate was achieved with a 40 versus 20 g dose of whey protein following whole-body resistance exercise [130]. Therefore, a dose up to 40 g may produce increased protein synthesis following resistance exercise incorporating large amounts of muscle, such as those followed by BB.

The high protein meals consumed by participants in this study likely exceeded the 20-40 g dose for maximal protein synthesis, potentially resulting in increased protein oxidation. However, the anabolic response to protein ingestion is a combination of protein synthesis and breakdown. Greater protein net balance has been produced from a 70 g versus 40 g dose of protein, primarily by decreasing the rate of protein breakdown [131]. Therefore, the frequent higher dosed protein meals consumed by BB may not only assist in supporting protein synthesis but also in reducing protein degradation during heavy resistance training. Furthermore, protein consumed by participants was primarily as part of a mixed nutrient meal, rather than a pure protein meal typically prescribed in the laboratory setting [2,129,130]. Carbohydrate and fat consumed in these meals would slow the digestive process, and time course of amino acid delivery to muscle cells. Any protein consumed in addition to the optimal 20-40 g dose for muscle protein synthesis in these mixed meals may be utilised for anabolic processes over the time course of digestion.

A protein intake of 2.3-3.1 g/kg of fat free mass has been suggested to be the most protective against losses of lean tissue during energy restriction in lean resistance trained athletes [132]. A higher protein requirement may be justified for BB during competition preparation, as they perform resistance and cardiovascular training, reduce energy intake, and achieve a lean condition [1]. Therefore the higher protein intake during the in-season to prevent loss of muscle mass in these participants may be justified.

During the in-season period, carbohydrate consumption was carefully timed around exercise. Glycogen is an important fuel substrate during resistance training [133], with glycogen depletion reported to reduce exercise performance [134]. Carbohydrate supplementation before and during resistance exercise improves performance of high volume, exhaustive exercise [135,136], a characteristic typical of bodybuilding training [9]. During in-season energy restriction, carbohydrate consumption following resistance training would assist in the replenishment of muscle glycogen, facilitating improved recovery and enhanced capacity to maintain training volume and intensity in subsequent sessions [137]. BB commonly perform multiple training sessions in a single day during the in-season, typically an aerobic and a resistance training session [9], therefore post-exercise carbohydrate ingestion would be important for maintaining training consistency.

Study participants discussed using a weekly re-feed day during the in-season period to boost training performance, provide a mental rest, and assist in body fat reductions. Intermittent energy restriction for weight loss has garnered significant recent clinical and research interest due to its hypothetical capacity to alleviate metabolic and behavioural adaptations associated with reduced energy intake. These adaptations include increased appetite associated with neuropeptide expression [138-140], reduced energy cost of physical activity [141], and hormonal effects that promote fat deposition and loss of lean mass [138,139]. Intermittent energy restriction, or "metabolic rest periods," have been shown to achieve similar weight and fat loss as continuous energy restriction, despite a higher overall energy intake [140,141]. Animal studies have shown that acute energy restoration (< 24 hours) can attenuate, or even abolish the orexigenic neuropeptide expression resulting from energy restriction [39,142]. The short-term restoration of energy balance, particularly through increased carbohydrate ingestion, would also increase intramuscular glycogen stores allowing greater resistance exercise performance [143].

During the peak week, participants discussed the use of several strategies to assist in achieving a lean, vascular appearance. Carbohydrate loading, and fluid and sodium manipulation had all been used by participants, with varying success. Only one empirical study has directly assessed changes in muscle girth from carbohydrate loading, finding no significant changes in relaxed or tensed muscle girths following a three-day carbohydrate depletion and subsequent three-day carbohydrate load [144]. This suggests carbohydrate loading may not produce the desired increase in muscle volume. Fluid and sodium manipulation to enhance visual appearance has not been empirically studied, however the desired improvement in muscle size and definition may not be obtained. Manipulating fluid intake to cause dehydration will result in a loss of fluid from all compartments, not just subcutaneous tissue [145,146]. Muscle water content is reduced [145], which may reduce muscle volume, an undesirable outcome for a competitive BB. Additionally, plasma volume is decreased with dehydration [145]; the common practice of "pumping up" prior to posing on stage may be less effective in increasing muscle size due to the detrimental effects of reduced plasma volume on muscle blood flow and volume [1]. Similarly, the manipulations in sodium consumption will not change the volume of the intracellular or extracellular compartments, only modifying urinary sodium output [147].

In the weeks following competition, participants reported an increased energy intake from a wider variety of foods, often leading to significant weight regain. Daily energy intake in the first two days post-competition was approximately twice that of the four weeks pre-competition in female BB, with an increase in body mass of 3.9 kg in the three weeks after competition [27]. Similarly, an average weight regain of 5.9 kg was reported in a group of male BB, with 46% of these participants reporting binge eating episodes in the days immediately following competing [28].

Supplement use, predominantly creatine and protein powders, was common amongst the BB interviewed, while "pre-workout" formulas had been trialled, with unwanted side-effects commonly reported. Protein and creatine supplementation have been demonstrated to be effective for increasing lean mass and strength [148,149]. The efficacy of so-called "pre-workout" supplements is yet to be confirmed. These products contain a combination of key ingredients such as creatine, caffeine, arginine, β-alanine and selected plant extracts [1,150,151]. Efficacy would be dependent on the supplement ingredients, and some produce side effects such as acute increases in blood pressure and difficulty sleeping [150].

BB have historically relied on magazines, other successful competitors, and more recently the internet, for information on dietary strategies [10]. This study identified the internet, in particular bodybuilding and strength and conditioning websites and forums, as a primary source of education, as well as other BB and coaches. In addition to the internet [152], athletes have previously identified family members, other athletes, coaches and registered dietitians as important sources of information regarding nutrition and dietary supplements [64,153,154]. Dietitians were not identified as sources of information by participants in this study, suggesting that their role needs better promotion amongst BB. With skills in dietary assessment, planning and body composition measurement, as well as evidence based strategies demonstrated to assist in the accrual of lean mass, dietitians have much expertise to provide BB, particularly novices who were considered by participants in this study to be vulnerable to inappropriate strategies promoted on the internet.

Study limitations include use of a small, homogeneous sample. Experienced BB were purposively sampled, therefore these results may not reflect the wider bodybuilding population, particularly inexperienced BB. Six of the seven participants had taken part in previous research which may introduce bias towards BB with greater access to education and inclined to follow a more evidence-based approach. Due to this potential bias, further research in a wider bodybuilding population is warranted.

CONCLUSION

Despite the common perception that BB follow extreme, unproven methods, the experienced BB in this study reported predominantly using dietary strategies which are recognised as evidence based. Inexperienced BB however may be vulnerable to more extreme strategies based on advice which is widely disseminated on the internet and social media.

Novel strategies identified in this study warrant further investigation. Intermittent energy restriction, and hormonal responses associated with short-term energy restoration, should be studied to determine benefits for weight loss whilst maintaining lean mass in both lean-athletic and obese populations. Peak week strategies implemented by BB, such as fluid and sodium manipulation, require further investigation to determine their efficacy and safety.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest. HOC receives payments from Sports Dietitians Australia for professional presentations delivered in a continuing education course for Sports Dietitians.

CHAPTER 6.

Physiological Implications of Preparing for a Natural Male Bodybuilding Competition

ABSTRACT

Background: This study aimed to describe the body composition and physiological changes which take place during the in-season and recovery periods of a group of natural bodybuilders.

Method: Natural male bodybuilders ($n = 9$) were assessed 16 (PRE16), 8 (8PRE) and 1 (PRE1) week(s) before, and 4 (POST4) weeks after a bodybuilding competition. Assessments included body composition, resting metabolic rate (RMR), serum hormones, and seven day weighed food and training diaries. Change in parameters were assessed using repeated measures analysis of variance.

Results: Dietary protein intake remained high throughout the study period (2.8 - 3.1 $g \cdot kg^{-1} \cdot d^{-1}$). Fat mass was significantly reduced from PRE16 to PRE1 (8.8 ± 3.1 *vs.* 5.3 ± 2.4 kg, $p < 0.01$). There was a small decrease in lean mass from PRE8 to PRE1 (71.8 ± 9.1 *vs.* 70.9 ± 9.1 kg, $p < 0.05$). No changes in RMR were observed ($p > 0.05$). Large reductions in total- and free-testosterone (16.4 ± 4.4 *vs.* 10.1 ± 3.6 $nmol \cdot L^{-1}$, $p < 0.05$; 229.3 ± 72.4 *vs.* 116.8 ± 76.9 $pmol \cdot L^{-1}$, $p < 0.05$), and IGF-1 (27.0 ± 7.7 *vs.* 19.9 ± 7.6 $nmol \cdot L^{-1}$, $p < 0.05$) occurred between PRE16 and PRE1. Lean mass and IGF-1 increased from PRE1 to POST4 (70.9 ± 9.1 *vs.* 72.5 ± 8.5 kg, $p < 0.05$; 19.9 ± 7.6 *vs.* 25.4 ± 9.3 $nmol \cdot L^{-1}$, $p < 0.05$).

Conclusion: Despite substantial reductions in fat mass, participants maintained almost all of their lean mass. The reduction in anabolic hormone concentration is likely attributable to the prolonged negative energy balance, despite a high dietary protein intake.

INTRODUCTION

Athlete physique traits have been associated with success in a variety of sports, including swimming [155], track and field [156], and rugby [157,158], as well as aesthetically judged sports such as gymnastics [159] and bodybuilding [160]. Competitive BB are judged on muscular size, symmetry and leanness, and employ a long-term approach to competition preparation [9]. In doing so, BB achieve the pinnacle of body composition translation for physique-based athletes: extreme leanness and hypermuscularity [13]. Rigorous diet and training practices are followed, and a range of dietary supplements are utilised [9,10]. The off-season period, lasting months to years, targets hypertrophy, and is characterised by an energy dense, high protein diet, plus large volumes of high intensity resistance training [9,10,161]. The in-season focuses on reductions in fat mass while maintaining lean mass through manipulation of diet and exercise variables [9,10]. In-season duration varies between athletes, typically lasting 12-26 weeks [161].

Given the extreme outcomes achieved, efforts have been made to describe the diet and training programs employed by BB, along with physiological adaptations that occur during the in-season. Early evidence from longitudinal research using small cohorts of males and females suggested BB make progressive reductions in energy intake, and increases in aerobic training volume, which are associated with desired decreases in fat mass during this phase [105,162]. More recent evidence has corroborated this and further shown that significant changes in anabolic hormone concentrations occur [163]. However, numerous studies have also suggested that BB may experience significant loss of lean mass during the in-season period [105], which is an undesirable outcome considering that they are judged on muscularity as well as leanness. On the basis of case study observations, there appears to be large associated reductions in resting metabolic rate (RMR) [12], which is likely a compensatory physiological response to reduce energy expenditure and mitigate the energy deficit, ultimately preventing further reductions in body mass [35]. From a bodybuilding perspective, this may limit fat mass loss, while potentially impeding muscle mass maintenance.

Although behavioural changes of BB, and their physiological associations, have individually been described, comprehensive longitudinal data in natural BB is currently limited to small cohorts and case studies [11-13,105,162,163]. Given the increasing popularity of competitive bodybuilding [1], and the success of BB in achieving high degrees of muscularity and leanness, gaining more data to inform and potentially better understand bodybuilding practices and the physiological implications is warranted.

Taking current evidence into account, there is a need to document longitudinal physiological responses of male, natural BB to competition preparation. Thus, utilising a cohort of high calibre competitors, this prospective study aimed to describe the body composition and physiological changes experienced by male, natural BB during the in-season and recovery periods of a bodybuilding contest. Based on documented changes associated with long-term energy restriction and high energy expenditure, we hypothesised the BB would experience large reductions in fat mass with concomitant reductions in lean mass, RMR, and anabolic hormones during the in-season period.

METHODS

Participants

To be eligible for inclusion, participants had to be male, drug-free BB, ≥18 years of age, preparing for competition in a natural federation. Recruitment methods included advertisements on the website and social media page of the Australasian Natural Bodybuilding and other social media pages. Advertisements were distributed at the Australasian Natural Bodybuilding national contest in October 2015, and to a database of BB held by the researchers from previous studies. Written informed consent was provided by all participants. Ethics approval was obtained from the University of Sydney Human Ethics Committee, project number 2015/425.

Procedures

A detailed description of testing protocols is included in Appendix D. Four testing sessions were conducted over a 20 week period. Three tests occurred during competition preparation (16, 8 and 1 week(s) pre-competition), and one occurred during competition recovery (4 weeks post-competition). The 16 week pre-competition testing duration was selected based on previous reports indicating average in-season preparation periods of 16 weeks in natural BB [161]. Participants presented to the laboratory between 0600-0800 hours after a 12 hour food and fluid fast, and having been instructed to abstain from caffeine, alcohol and exercise for 12 hours. Participants were advised to avoid physical activity, such as walking, jogging and cycling, the morning of assessment. A urine sample was collected upon arrival. All participants presented in a euhydrated state, confirmed via urinary specific gravity assessment (UG-α, Atago, Japan). Stature (WS220S stadiometer, Wedderburn, Sydney, Australia) and mass (Wildcat, Mettler

Toledo, Ohio, United States) in swimwear were measured according to standardised protocols [164], before a battery of examinations was performed in the following order.

Bioelectrical Impedance Analysis (BIA)

After 10 minutes rest in a supine position, bioimpedance spectroscopy was used to estimate total body water (TBW), intracellular fluid (ICF), and extracellular fluid (ECF). According to manufacturer recommendations (IMP SFB7, ImpediMed, Queensland, Australia), dual tab electrodes were placed on the hand and foot on the right side of the body. The device scans 256 frequencies, and utilises Cole modelling with Hanai mixture theory . The average of three trials was used to calculate TBW, ICF, and ECF. Values were calculated internal to the BIA device.

Resting Metabolic Rate (Resting energy expenditure)

Resting energy expenditure was estimated using indirect calorimetry with a metabolic cart (Quark CPET, COSMED, Rome, Italy). Participants remained rested after BIA measurement in the same position. Expired respiratory gas analysis began with the participant instructed to breathe normally. Expired air was collected using a face mask for 30 minutes, measured at 30-second intervals. A five minute period with VO_2 and VCO_2 coefficient of variation ≤ 10% during the second 15 minutes was used to quantify resting energy expenditure and respiratory exchange ratio [165]. Participants were instructed to lie still but not fall asleep. The gas analyser was calibrated immediately prior to testing with a known gas concentration (5% CO_2, 16% O_2, 79% N_2), and a three litre calibration syringe (Hans Rudolf, USA) was used to calibrate the volume transducer. Testing took place in a quiet, dimly lit, thermo-neutral room.

Dual-energy X-Ray Absorptiometry (DXA)

A whole body DXA scanner, (Lunar Prodigy, GE Medical Systems, Madison, WI) was used to estimate body composition. Total fat mass and lean mass were determined using the system's software package (enCORE 2011 version 13.60.033; GE Healthcare). The DXA was calibrated with phantoms as per manufacturer guidelines each day prior to measurement. Participants were placed in a standardised position on the scanning bed (feet neutral, ankles strapped together, arms straight, palms down and isolated from the body, face up with neutral chin) [166], wearing only swimwear. Measurements were performed by a licensed operator, with excellent test-retest reliability for fat mass (ICC: 0.998; CV: 3.7%) and lean mass (ICC: 0.999; CV: 3.7%). The typical error of measurement for a Lunar Prodigy established by repeat measurements has been reported as 0.4% and 1.9% for lean mass and fat mass, respectively [167].

Anthropometry

An accredited anthropometrist (level 1 ISAK) with a technical error of measurement of 2.4% used surface anthropometry (Harpenden skinfold calipers, Baty International, West Sussex, UK) to quantify subcutaneous fat thickness according to the ISAK level 1 protocol which includes eight skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, mid-abdominal, front thigh and medial calf sites) [164]. Measurements were made in duplicate, with the mean value reported if within 5% variation. In the case of greater than 5% variation between measures, a third measurement was taken, and the median measure reported.

Blood parameters

Venous blood samples were obtained by venepuncture from the antecubital vein. Samples were centrifuged, then serum separated and stored at -80°C for later analysis at a NATA accredited hospital laboratory. Testosterone, sex hormone binding globulin and cortisol were measured using a competitive electrochemiluminescence immunoassay on a Cobas 8000 analyser (Roche, Manheim, Germany). Free testosterone was calculated using the measured testosterone and sex hormone binding globulin values. Insulin-like growth factor-1 (IGF-1) was measured using a sandwich chemiluminescence immunoassay on a Liaison XL analyser (DiaSorin, Italy). Leptin and adiponectin were analysed by commercially available radioimmunoassay kits (EMD Millipore, Billerica, USA). Insulin was analysed by chemiluminescent microparticle immunoassay using an Architect System (Abbot Laboratories, Abbot Park, USA). Blood lipids were analysed by an enzymatic colorimetric assay on a Cobas 8000 analyser (Roche, Manheim, Germany).

Diet and Exercise

Seven-day weighed food and training diaries were completed at each time point. Participants documented all food, fluid and supplements consumed during the seven day period. All resistance and aerobic exercise was documented in the training diary. Food diaries were analysed using the FoodWorks program (Version 8; Xyris Software, Brisbane, Australia), and included analysis of reported dietary supplement consumption. Macronutrient intake distribution was calculated as reported elsewhere [168]. However in brief, reported foods were separated into eating occasions, with macronutrient totals for each eating occasion extracted from the FoodWorks program. Resistance training volume (repetitions·weight·sets) was determined for the total body, upper body (exercises using predominantly upper body muscles) and lower body (exercises using predominantly lower body muscles).

Analysis

Means and standard deviations were calculated for all test parameters. Normality of data was assessed using the Shapiro-Wilk test. Independent samples t-tests were performed to test for differences between participants who commenced their in-season diet prior to baseline testing, and those who had not. For normally distributed data, repeated measures analysis of variance were performed to test for changes between time points, with Greenhouse-Geiser corrections used when the assumption of sphericity was violated. Where significant change was detected, post hoc pairwise comparisons with Bonferroni correction were performed. Where data were not normally distributed, Friedman analyses of variance by ranks were run, and Wilcoxon sign-rank test with Bonferroni correction were performed where significant differences were detected. Relative effect sizes (Cohen's *d*) were calculated for all significant findings using the following formula: (mean $value_1$ – mean $value_2$)·pooled SD^{-1}. Effect sizes were considered small (0.2), medium (0.5), or large (0.8) [78]. Missing data were imputed using the last result carried forward method. Analyses were conducted using IBM SPSS statistics version 22 (IBM SPSS; Chicago, Illinois, USA). Significance was set at $p < 0.05$.

RESULTS

Eleven BB consented to participate in the study. Two withdrew after baseline testing due to withdrawal from competition, with the remaining nine (29.0 ± 9.5 years, 177.9 ± 2.5 cm, 83.7 ± 8.9 kg, 6.0 ± 6.6 years bodybuilding participation) included in analyses. Results are displayed with zero representing the time of competition, therefore PRE16 represents the measurement occurring 16 weeks before competition, POST4 represents the measurement occurring four weeks after competition. Two participants failed to return for POST4 testing. Eight participants competed at a national competition in their respective divisions, with three placing in the top 10, two placing third, two placing second, and one placing first. The ninth participant placed third at an international competition.

Diet

Four participants had commenced their in-season diet prior to PRE16 measurements, three commenced during the week of PRE16 measurements, while the remaining two commenced after PRE16 measurements. Dietary intake is presented in Table 6.1. There were no significant differences in dietary intake at PRE16, or changes in dietary intake from PRE16 to PRE1, between participants who commenced their in-season diet before versus during or after PRE16 ($p > 0.05$). Energy and macronutrient values include contributions from supplements. There were no significant differences in energy intake across measurement points ($p = 0.071$). No significant changes in total ($g \cdot d^{-1}$) or relative ($g \cdot kg \cdot d^{-1}$) protein intake were detected ($p = 0.506$ and $p = 0.625$, respectively). There were no significant differences in carbohydrate or fat intake during pre-competition, however significant differences were detected between PRE8 and POST4 time points for total ($p = 0.035$, $d = -0.8$) and relative ($p = 0.032$, $d = -0.8$) carbohydrate values.

Energy and macronutrient distribution results are presented in Table 6.1. Throughout in-season testing, participants consumed 5.2 ± 1 meals$\cdot d^{-1}$. Across all participants and meals consumed during testing, $81.3 \pm 19.8\%$ of meals were above the $0.25\ g \cdot kg^{-1}$ of protein threshold [169].

Dietary supplements were used during the pre- ($n = 7$) and post-competition ($n = 8$) periods. Dietary supplement contribution to total daily intake is presented in Table 6.1. The most commonly used dietary supplements were whey protein (n = 7), creatine (n = 5), branched chain amino acids (n = 4), and glutamine (n = 3).

Four participants reported implementing a "re-feed" day or meal during the PRE16 and PRE8 testing weeks. On these days, there was a 46.2 ± 21.0% increase in energy, a 114 ± 41% increase in carbohydrate, and a 63 ± 66% increase in fat, while protein was reduced by 4 ± 11%.

Reported training volumes are presented in Table 6.1. No significant differences in resistance training volume were found between testing points ($p > 0.10$). A significant difference in aerobic training volume was found ($p = 0.01$), however post hoc analysis with Bonferroni correction failed to reach significance ($p > 0.10$).

Table 6.1. Dietary intake during competition preparation and recovery.

	PRE16	PRE8	PRE1	POST4
Energy ($kJ \cdot d^{-1}$)	12,585 ± 4,222	11,294 ± 3,192	11,690 ± 3,470	13,738 ± 3,398
Energy from supplements ($kJ \cdot d^{-1}$)	1,242 ± 1,674	1,043 ± 1,325	1,098 ± 1,686	1,069 ± 1,264
Energy ($kJ \cdot meal^{-1}$)	2,051 (75–12,506)	2,085 (20–6,767)	2,058 (270–7,358)	2,261 (15–9,729)
Protein ($g \cdot d^{-1}$)	266.9 ± 89.1	245.6 ± 82.0	263.4 ± 101.9	259.3 ± 109.3
Protein ($g \cdot kg^{-1} \cdot d^{-1}$)	3.0 ± 0.7	2.8 ± 0.6	3.1 ± 0.9	2.7 ± 0.9
Protein from supplements ($g \cdot d^{-1}$)	40.5 ± 42.7	42.5 ± 49.4	39.2 ± 43.0	35.7 ± 31.2
Protein ($g \cdot meal^{-1}$)	49 (0–162)	49 (0–160)	47 (2–136)	41 (0–127)
Protein ($g \cdot kg^{-1} \cdot meal^{-1}$)	0.6 (0–2.05)	0.6 (0–2.1)	0.6 (0–1.9)	0.5 (0–1.5)
Carbohydrate ($g \cdot d^{-1}$)	242.8 ± 100.2	206.0 ± 91.3	232.2 ± 99.8	310.1 ± 150.8[b]†
Carbohydrate ($g \cdot kg^{-1} \cdot d^{-1}$)	2.9 ± 1.2	2.6 ± 1.2	3.0 ± 1.4	3.8 ± 1.9[b]†
Carbohydrate ($g \cdot meal^{-1}$)	42 (0–305)	34 (0–253)	40 (0–331)	46 (0–270)
Carbohydrate from supplements ($g \cdot d^{-1}$)	18.8 ± 29.3	10.6 ± 14.7	14.9 ± 26.7	14.5 ± 21.0
Fat ($g \cdot d^{-1}$)	97.6 ± 58.2	88.7 ± 48.6	79.5 ± 47.8	102.8 ± 42.8

Fat from supplements ($g \cdot d^{-1}$)	6.4 ± 14.5	4.1 ± 7.3	7.1 ± 16.6	6.2 ± 13.2
Fat ($g \cdot meal^{-1}$)	13 (0–155)	14 (0–94)	11 (0–60)	18 (0–91)
Resistance training volume ($kg \cdot week^{-1}$)	82,461 ± 34,582	94,317 ± 44,240	66,553 ± 41,996	79,620 ± 45,304
Upper body ($kg \cdot week^{-1}$)	39,958 ± 17,232	42,368 ± 19,647	32,753 ± 14,385	37,432 ± 15,384
Lower body ($kg \cdot week^{-1}$)	42,503 ± 24,234	51,247 ± 37,997	33,800 ± 33,697	41,735 ± 34,225
Aerobic training volume ($minutes \cdot week^{-1}$)	65 ± 72	135 ± 131	143 ± 146	3 ± 7

Data are presented as mean ± SD, or median (range). Dietary values include contribution of supplements. Resistance training volume calculated as (resistance · repetitions · sets). [a] significantly different to PRE16; [b] significantly different to PRE8; [c] significantly different to PRE1. † $p < 0.05$; ‡ $p < 0.01$.

Body composition

Body composition results are presented in Table 6.2 and Figure 6.1. On average, 85 ± 38% of mass lost during pre-competition testing was fat mass (range 29–136%). Medium, large, and small reductions in subcutaneous adiposity estimated by anthropometry occurred between PRE16 and PRE8, PRE16 and PRE1, and PRE8 and PRE1 ($p = 0.018$, $d = 0.5$; $p = 0.004$, $d = 0.9$; $p = 0.01$, $d = 0.4$, respectively). No significant changes were found for TBW, ECF or ICF ($p > 0.1$). There were no differences in fat mass, lean mass, percentage change in fat mass or lean mass, or proportion of mass lost as fat mass, between participants who commenced their in-season diet before versus during or after PRE16 ($p > 0.05$).

Table 6.2. Body composition, resting metabolic rate, and blood parameters during competition preparation and recovery.

		Reference range	PRE16	PRE8	PRE1	POST4
Body Composition						
DXA	Total mass (kg)		83.7 ± 8.9	81.8 ± 9.1	79.6 ± 9.0[a]‡,[b]†	83.0 ± 7.7[c]‡
	Fat mass (kg)		8.8 ± 3.1	6.6 ± 2.4	5.3 ± 2.4[a]‡	7.1 ± 3.0[c]†
	Lean mass (kg)		71.4 ± 8.9	71.8 ± 9.1	70.9 ± 9.1[b]†	72.5 ± 8.5[c]†
BIA	TBW (L)		54.3 ± 6.9	54.6 ± 7.0	53.7 ± 6.7	54.8 ±6.3
	ECF (L)		21.4 ± 2.5	21.4 ±2.8	21.0 ±2.5	21.7 ± 2.3
	ICF (L)		32.9 ± 4.5	33.2 ± 4.4	32.7 ± 4.3	33.1 ± 4.2
Skinfolds	Sum of 8 sites (mm)		47.7 ± 12.7	42.0 ± 11.4[a]†	37.3 ± 11.1[a]‡,[b]†	43.3 ± 15.8
Resting Metabolic Rate						
	kJ·d^{-1}		10,036.3 ± 1,592.0	9,706.4 ± 1,728.4	9,805.1 ± 1,800.6	10,160.0 ± 1,313.8
	kJ·kg^{-1}·d^{-1}		120.4 ± 18.7	119.5 ± 23.6	123.5 ± 19.1	123.1 ± 19.0
	kJ·kg lean mass^{-1}·d^{-1}		141.2 ± 20.2	136.2 ± 25.0	139.2 ± 22.4	141.5 ± 21.3
Hormones						
	Testosterone (nmol·L^{-1})	10.0 - 30.0	16.4 ± 4.4	11.5 ± 5.3	10.1 ± 3.6[a]†	15.1 ± 4.5
	Free testosterone (pmol·L^{-1})	80 - 370	229.3 ± 72.4	153.9 ± 85.4	116.8 ± 76.9[a]†	220.2 ± 95.4
	IGF-1 (nmol·L^{-1})	14.2 - 58.8	27.0 ± 7.7	23.4 ± 7.4	19.9 ± 7.6[a]†	25.4 ± 9.3[c]†
	Cortisol (nmol·L^{-1})	170 - 500	358.0 ± 107.8	328.7 ± 71.7	364.8 ± 74.0	314.9 ± 109.9
	Insulin (pmol·L^{-1})	10 - 96	24.1 ± 7.4	20.7 ± 5.5	18.0 ± 7.0	39.7 ± 15.7

	Leptin (ng·mL^{-1})	2.0 - 5.6	2.8 ± 1.9	2.8 ± 1.6	3.2 ± 2.0	4.1 ± 2.5
	Adiponectin (μg·mL^{-1})	3.0 - 30.0	13.8 ± 5.0	14.3 ± 4.6	19.0 ± 12.6	22.2 ± 11.1
Lipids						
	Total Cholesterol (mmol·L^{-1})	≤ 5.2	4.0 ± 0.8	3.9 ± 0.8	4.0 ± 0.9	4.1 ± 0.8
	HDL (mmol·L^{-1})	1.0 - 2.5	1.5 ± 0.4	1.4 ± 0.3	1.7 ± 0.4	1.7 ± 0.5
	LDL (mmol·L^{-1})	≤ 3.5	2.2 ± 0.6	2.2 ± 0.9	2.1 ± 0.7	2.1 ± 0.6
	Triglycerides (mmol·L^{-1})	≤ 2.5	0.7 ± 0.3	0.6 ± 0.2	0.5 ± 0.2	0.8 ± 0.4

Mean ± SD for all values. Total mass, fat mass, lean mass measured by DXA; TBW, ECF and ICF measured by BIA. Resting metabolic rate presented as total and relative (total mass, lean mass). [a] significantly different to PRE16; [b] significantly different to PRE8; [c] significantly different to PRE1. † $p<0.05$; ‡ $p<0.01$. DXA, dual-energy x-ray absorptiometry; BIA, bioelectrical impedance analysis; TBW, total body water; ECF, extracellular fluid; ICF, intracellular fluid; RMR, resting metabolic rate; HDL, high density lipoprotein; LDL, low density lipoprotein.

Resting metabolic rate.

No significant changes in RMR were detected across the study period when assessed absolute ($p = 0.87$) or relative to lean mass ($p = 0.91$; Table 6.2, Figure 6.1). No differences were found for RMR or percentage change in RMR between participants who commenced their in-season diet before versus during or after PRE16 ($p > 0.05$).

Blood parameters

Blood parameter results are presented in Table 6.2 and Figure 6.2. Five, four and one participant dropped below reference ranges for serum testosterone, free testosterone and IGF-1 concentrations during pre-competition testing, respectively. No differences were found in blood parameters or percentage change in blood parameters between participants who commenced their in-season diet before versus during or after PRE16 ($p > 0.05$).

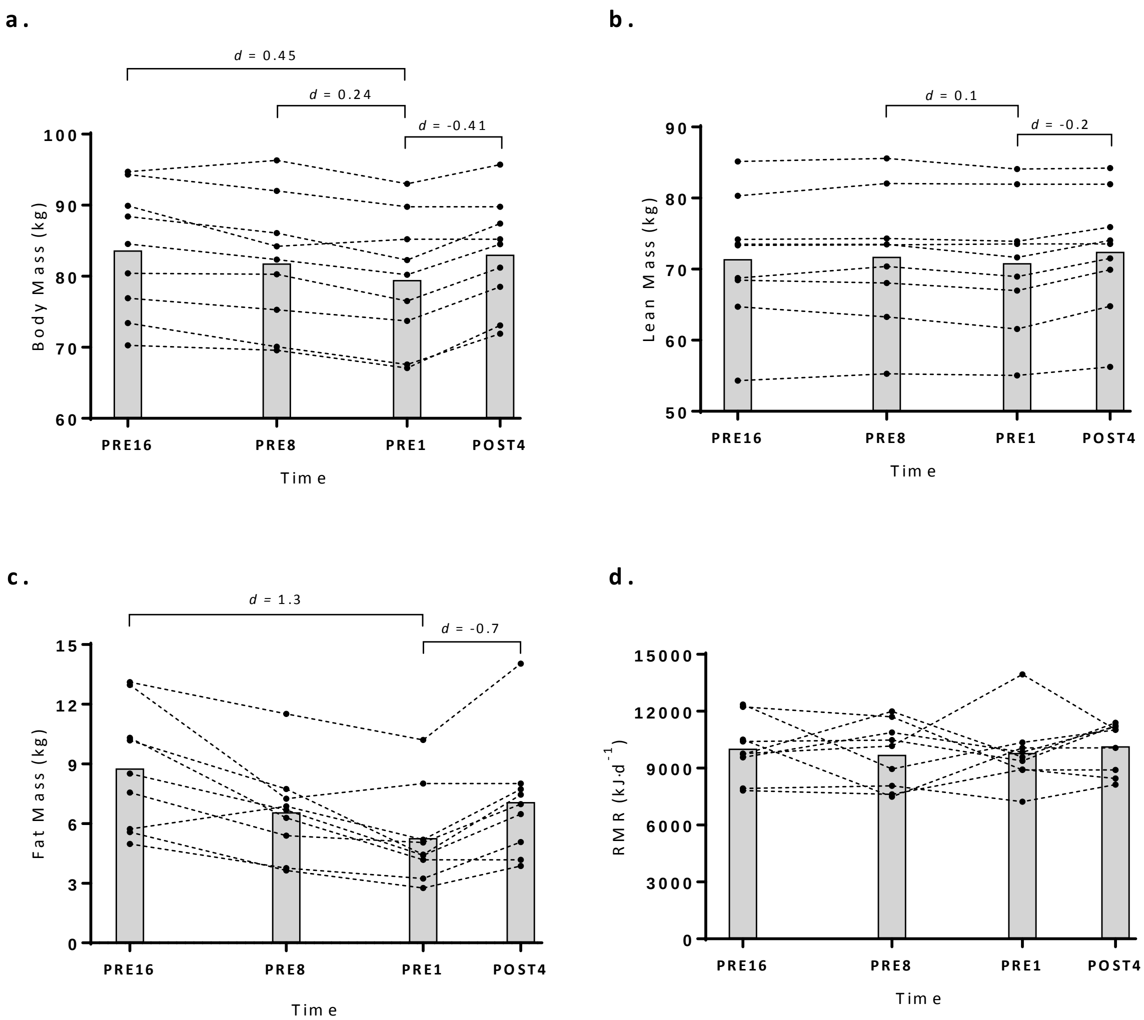

Figure 6.1. Body composition and resting metabolic rate changes. Enclosed dots indicate individual data; bars indicate mean. Effect sizes indicate changes in mean. Body mass, lean mass, fat mass, measured using dual-energy x-ray absorptiometry. RMR, resting metabolic rate. *d* indicates effect size between time points.

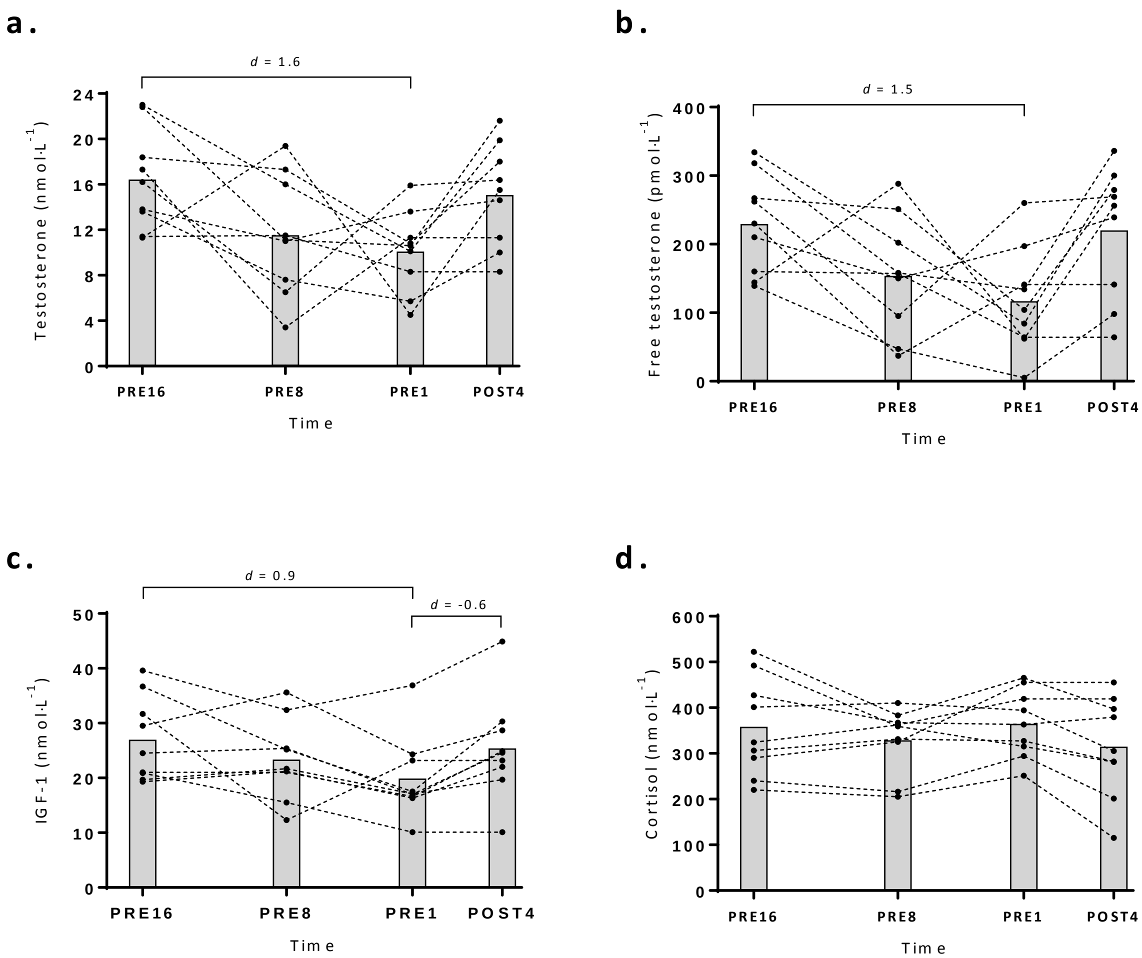

Figure 6.2. Serum hormone changes. Enclosed dots indicate individual data; bars indicate mean. Effect sizes indicate changes in mean. *d* indicates effect size between time points.

DISCUSSION

This prospective study aimed to describe body composition and physiological changes in male, natural BB during competition preparation and recovery. We hypothesised large reductions in fat mass, with concomitant reductions in lean mass, RMR and anabolic hormones during the in-season period. BB in this study lost significant amounts of fat mass, with only small losses in lean mass, and no change in RMR. During the four months of pre-competition measurement, all participants reduced fat mass to low levels, in some cases to the lower limits of human fat mass [170]. There was large variability in the proportion of body mass lost as fat, although the average ratio was high (85 ± 38%, range 31–136%). Despite these body composition changes, RMR remained unchanged throughout the competition preparation period, while serum testosterone and IGF-1 concentrations were significantly reduced. These findings are valuable, given the paucity of longitudinal research in natural BB.

Body composition

As hypothesised, there were significant reductions in fat mass measured via DXA (mean reduction = 3.5 kg). Similarly, a moderate reduction in the sum of eight skinfolds occurred (mean reduction = 10.7 mm). The fat mass loss documented in this study was small relative to those previously reported, likely resulting from the shorter assessment period. In case reports, natural BB have been shown to lose up to 10.4 kg of fat mass during competition preparation [11-13]. The BB in our study were at a moderately low fat mass at PRE16, which may also account for the smaller reductions (8.8 ± 3.1 kg compared with 11.7–15.9 kg in case studies). Further, four participants had commenced their in-season dieting at PRE16 which would in part explain the low initial fat mass and smaller reduction in fat mass.

A common and undesired side-effect of prolonged energy restriction is a loss of lean mass. This is particularly evident in lean individuals, including natural BB [11,12]. Indeed, amongst lean individuals in an energy deficit, the ratio of lean to total mass lost typically increases [171]. However, the BB in this cohort were mostly successful at maintaining lean mass. Fat loss accounted for 85% of total mass lost, although this varied widely between participants (range 29–136%). There were no statistical changes in lean mass seen between PRE16 and PRE8, and only a small reduction between PRE8 and PRE1 (mean difference = 0.9 kg, $d = 0.1$). Reductions in lean mass in the previously cited natural BB case studies ranged from 2.8–6.6 kg [11-13]. The success of the BB in our study in maintaining lean mass may be attributed to a small energy deficit used throughout the in-season. A smaller energy deficit during a period of weight reduction has been demonstrated as an effective mechanism for maintaining lean mass [172]. The maintenance of lean mass is even more significant considering the low fat mass observed at PRE16, given previous research demonstrates leaner individuals lose a proportionately greater amount of lean mass during an energy deficit [170].

A second possible explanation for the lean mass maintenance is the high dietary protein intake. A higher protein intake has been demonstrated as an effective mechanism for limiting lean mass loss during energy restriction in resistance trained individuals [173]. In athletes, to optimise the ratio of lean mass to fat mass loss during an energy deficit, a protein intake of 1.8–2.7 $g \cdot kg^{-1} \cdot d^{-1}$ has been suggested [174]. In already lean individuals, a protein intake dependent on fat free mass has been proposed: 2.3–3.1 g·kg fat free $mass^{-1} \cdot day^{-1}$ may be effective in achieving lean mass maintenance during an energy deficit [132]. Throughout this study, participants consumed 2.8–3.1 $g \cdot kg^{-1} \cdot d^{-1}$, and 3.3–3.6 g·kg lean $mass^{-1} \cdot day^{-1}$, thus met or exceeded these recommendations.

This high protein intake and smaller overall energy deficit would help negate physiological adaptations associated with weight loss which drive a reduction in lean mass.

In conjunction with an increased total protein intake, distribution of protein is reported to be an effective means of maximising muscle protein synthesis [2]. Participants in this study ate 5.2 ± 1 meals·d^{-1}, with 81.3 ± 19.8% of meals surpassing the 0.25 g·kg^{-1} dose recommended [169], facilitating conditions for building and maintaining lean mass, despite remaining in negative energy balance. The inclusion of a high protein post-exercise meal would also assist in increasing muscle protein synthesis [175].

Regular high intensity resistance training would aid in attenuation of lean mass reduction in these BB. Study participants maintained a high volume of resistance training (Table 6.1). The muscle protein synthesis response to protein is reduced during an energy deficit. However, resistance exercise during the energy deficit has been demonstrated to stimulate protein synthesis to rates similar to those during energy balance [176]. This uninhibited muscle protein synthesis response to protein ingestion associated with resistance training would counter the catabolic effects of a negative energy balance, and hence assist in the maintenance of lean mass.

Resting metabolic rate

Reductions in RMR are typically seen during periods of energy restriction and weight loss [177], which is attributed to changes in lean mass and fat mass. Our results showed no change in RMR during the pre-competition period (mean difference 231 kJ·d^{-1}). This result contrasts those found in previous BB case studies, where small (752 kJ·d^{-1}) and large reductions (4746 kJ·d^{-1}) have been reported [12,13]. Maintenance of RMR in the current study is likely attributable to the very small reductions in lean mass observed, and the high intensity resistance training performed throughout the pre-competition period [178]. Resistance training during a period of negative energy balance has been shown to alleviate reductions in 24 hour resting energy expenditure [178]. By maintaining lean mass, and subsequently resting energy expenditure, the BB in this study required smaller reductions in energy intake to maintain an overall negative energy balance. This smaller energy deficit would result in continued fat mass reductions, while limiting reductions in lean mass and subsequently RMR, thereby producing a positive feedback cycle allowing the achievement of body composition modification.

Blood parameters

Circulating anabolic hormone concentrations are sensitive to energy status. Periods of short-term energy deficit may produce acute reductions in testosterone, which are accentuated when the energy deficit is prolonged [35,179]. This anti-anabolic response aids in reducing protein synthesis and energy expenditure [180], and may correspond with a loss of lean mass [35]. During the pre-competition period, total and free testosterone reduced by 38% and 49%, respectively, while IGF-1 reduced by 26%. These reductions compare to the reduction in testosterone measured during a six month competition preparation of a male BB (75% reduction) [13]; while a 15% mean reduction in testosterone was found in seven male BB during the final 11 weeks of competition preparation [163].

The hormonal response to energy restriction is likely attributable to low energy availability [181]. Similar reductions in serum testosterone to those found in this study are evident in competitive jockeys, who undertake periods of energy restriction resulting in low energy availability in order to make weight [182]. As no significant reductions in energy intake were found, and exercise energy expenditure was unable to be accurately evaluated, low energy availability cannot be confirmed in this study.

Despite reductions in anabolic hormone concentrations, BB in this study were still able to prevent large losses of lean mass, indicating the lean mass response to a continual energy deficit was not associated with changes in testosterone or IGF-1 concentrations. It also suggests the high protein intake and resistance training program employed by participants was sufficient to counteract the anti-anabolic effects of these hormonal changes.

The rapid return to baseline values for testosterone and IGF-1 concentrations post-competition is also of significance. This may reflect energy deficit cessation. One case study has examined hormonal changes after a bodybuilding competition, finding testosterone increased to 94% of baseline concentrations after three months of increased energy intake [13]. A similar restoration of testosterone concentration was found among army rangers during 2–6 weeks of recovery from an eight week period of high energy expenditure and low energy intake [183]. The rapid increase of anabolic hormone concentrations after competition observed in our study suggest there may be no significant physiological detriment associated with a short-term reduction in anabolic hormones when protein intake and resistance training are maintained.

Limitations of this study include a modest sample size (n = 9) which requires consideration when interpreting the non-significant findings. With a larger sample size, trends identified may reach statistical significance, and thus provide more insight into the changes which occur during competition preparation and recovery. A 12-hour exercise-free period in preparation for testing was implemented, due to the high frequency exercise regimen employed by participants. This limited time frame relative to current guidance [165] may have inflated RMR results, as metabolic rate may remain elevated for up to 48 hours following resistance exercise [165]. Additionally, a face mask was used to collect expired gas for RMR assessment, rather than a ventilated hood, although this may not significantly affect results [165]. The lack of statistically significant change in dietary intake during pre-competition testing may be attributed to the testing timeline. Strategies used by participants during the PRE1 testing week incorporate an increased carbohydrate and hence energy intake. Rather than observing a decrease in energy intake between PRE8 and PRE1 as predicted, a small, insignificant increase was observed. One may speculate that a modified testing timeline, including testing two weeks before the contest, would observe significant reductions in energy, carbohydrate, and fat intake compared to PRE16 values. More frequent testing, for example every two to four weeks leading to competition as used in previous case studies [11], may allow closer observation of changes. The modest sample size of this study may also explain the insignificant changes in dietary parameters. The inability to determine energy expenditure of participants from exercise parameters limits the calculation of energy balance of participants. Including a measure of energy expenditure, such as a wearable monitor for estimating total energy expenditure, would allow calculation of energy balance, and a more detailed insight into the nature of body composition and physiology changes occurring during competition preparation. Several participants in this study had commenced in-season dieting before PRE16, therefore this time point does not reflect a true off-season status in these participants, thus changes observed may not encompass total changes typically occurring from off-season to competition. The use of DXA to assess lean mass during dietary manipulation is limited due to the inability to differentiate glycogen associated lean mass from protein lean mass, and therefore changes in muscle glycogen content will increase measures of lean mass [184]. Although a 12-hour fast was implemented prior to testing, muscle glycogen stores need to be considered when interpreting the lean mass results. However there were no significant changes in TBW and ICF, which suggests lean mass changes are likely not attributable to glycogen changes.

CONCLUSION

These BB demonstrated significant reductions in fat mass with only small reductions in lean mass. We suggest that the maintenance of resistance training volume and an evenly distributed, high protein intake during the competition preparation may have provided a stimulus to maintain lean mass whilst reducing fat mass. A subsequent outcome of maintaining lean mass was maintenance of RMR, likely enabling participants to continue with only small reductions in energy intake. Assessing the effect of preparation strategies employed by these BB in other athlete populations may help identify recommendations that assist in modification of body composition.

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CONFLICTS OF INTEREST

The authors report no conflict of interest. HOC and GS receive payments from Sports Dietitians Australia for professional presentations delivered in a continuing education course for Sports Dietitians

CHAPTER 7.

Longitudinal Trends in Muscle Dysmorphia Symptomatology in Bodybuilders During Preparation for a Bodybuilding Contest: An Exploratory Pilot Study

ABSTRACT

Background: Muscle dysmorphia (MD) is characterised by a distorted self-perception and a drive for muscularity. Symptoms of MD are yet to be examined longitudinally, in particular during a period of significant body composition change. The aim of this pilot study was to document trajectories of MD and eating disorder (ED) symptomatology in bodybuilders (BB) during contest preparation.

Method: Male, drug-free BB (n = 9) participated in this exploratory pilot study conducted during the final 16 weeks of competition preparation. Assessments included body composition, diet, and MD and ED symptomatology. Repeated measures linear mixed modelling was used to derive estimates of change during competition preparation, while Pearson correlations were used to assess relationships between MD symptoms and body composition and dietary changes.

Results: No significant changes were found for MD and ED symptomatology, or fat and muscle discrepancy indices. MD symptomatology was negatively correlated with change in energy (r = -0.707) and fat (r = -0.713) intake.

Conclusion: Despite body composition shifting towards extreme leanness and muscularity, these BB were not less concerned about their physique, instead displaying a robustness of MD symptoms. BB displaying increased MD symptomatology may present a disconnect between actual body composition and attitudes around muscularity.

INTRODUCTION

Body dissatisfaction in males is now increasingly recognised [185]. Unlike females, male dissatisfaction typically presents as a desire to increase muscularity and leanness, reflecting the current ideal male physique [59]. This ideal male physique is typically defined as muscular, lean and athletic [59,60]. Muscularity enhancing endeavours, driven by the pursuit of this ideal physique, include dietary and exercise interventions. The pathological extreme of this pursuit is muscle dysmorphia (MD), characterised by (i) a distorted self-perception, whereby one views themselves as small and weak, often despite well-developed muscularity, and (ii) a concomitant drive for muscularity [14]. Attitudinal and behavioural symptoms reflect this self-perception, and include meticulous training and dietary schedules, and marked anxiety experienced upon deviation from these regimens [14].

In the context of athletic performance, sport pressures regarding size and shape may also drive muscularity-enhancing behaviours and attitudes [112]. Participation in sports with a focus on increased muscularity and strength may facilitate MD symptomatology, with evidence suggesting MD may affect a broad range of athletic groups, including footballers and powerlifters [51]. The greatest implicit overlap between MD and athletics lies in the sport of bodybuilding, where success is dependent on muscular size, symmetry and leanness. Bodybuilders (BB) employ a structured, long-term approach to competition, transitioning from an off-season phase which targets muscular hypertrophy, through to an in-season phase that targets extreme leanness and maintenance of muscle mass [161]. A rigorous training routine is developed, and strict dietary practices are engaged in order to achieve these physical outcomes [161].

Both BB and those afflicted with MD are oriented towards extreme muscularity and leanness, although participation in bodybuilding is not in itself a pathological endeavour [117]. Furthermore, disordered eating behaviours are associated with MD symptomatology, and pathological eating is central in presentations of MD symptoms in BB [186]. To date though, no study has examined the trajectory of MD symptomatology throughout a period of significant body composition change. Previous research has demonstrated resistance training to ameliorate MD symptoms [17], while eating disorder (ED) symptomatology has been shown to fluctuate based on the engagement in safety- and symptomatic-behaviour [124]. The in-season period of competition preparation entails engagement in extreme diet and exercise behaviours, and achievement of a lean and muscular physique. Based on this engagement, coupled with the noted drive for muscularity and leanness synonymous with MD [14], alterations in MD symptoms may result during this period. Thus, it is essential to determine whether prolonged engagement in extreme dietary and exercise behaviours, resulting in a body composition shift towards the lean and muscular ideal physique, promote alterations in MD symptomatology. Given the diet and exercise habits embraced, and the extreme body composition outcomes achieved by BB [187], the in-season period is an ideal context to examine the trajectory of MD symptomatology during a period of significant body composition change.

The aims of this exploratory pilot study were to document trajectories of MD and ED symptomatology in a small sample of BB during bodybuilding contest preparation. Due to the absence of empirical evidence in this domain, no a priori hypotheses were developed.

METHODS

Participants

Participants were male, at least 18 years of age, drug-free and actively competing BB. Recruitment efforts included advertisements on websites and social media pages of bodybuilding organizations, and the distribution of flyers at the Australasian Natural Bodybuilding national contest in October 2015 and to a database of BB held by the researchers from previous studies. Written informed consent was provided by all participants. Ethics approval was obtained from the University of Sydney Human Ethics Committee, project number 2015/425.

Procedures

A detailed description of testing protocols is included in Appendix D. Data collection occurred on five occasions over a 16 week period, at 16 (PRE16), 12 (PRE12), 8 (PRE8), 4 (PRE4), and 1 (PRE1) week(s) before competition. This timeline accords with evidence indicating a typical bodybuilding contest preparation period of approximately 16 weeks [161]. To control for the potentially moderating effect of resistance training on MD symptomatology [17], all measures were completed on a day in which participants had exercised.

Assessment tools

The Muscle Dysmorphic Disorder Inventory (MDDI) [120] is a validated and widely-used 13-item questionnaire measure of MD symptomatology that comprises three subscales; drive for size, appearance intolerance, and functional impairment. Total scores range from 13 to 65, with higher scores reflecting greater MD psychopathology. The MDDI yields good psychometric properties, although in the present study internal consistency was questionable (Cronbach's α = 0.67). However, given the exploratory nature of the study this level was considered sufficient.

The Bodybuilder Image Grid - Original (BIG-O) [120] was designed to measure perceptual body image disturbance in males and perceived attractiveness of the male body to both men and women. The grid contains 30 silhouettes varying in degrees of adiposity along the x-axis and muscularity along the y-axis, ranging from "extremely low body fat" to "extremely high body fat", and from "extremely low muscle mass" to "extremely high muscle mass". Participants were asked to select the silhouette which best represents (a) their current body type, and (b) their ideal body type. To measure perceptual disturbance, a discrepancy index was calculated for body fat (current fat - ideal fat = desired fat) and muscle mass (ideal muscle - current muscle = desired muscle) by subtracting the corresponding column and row scores. A higher index score indicates a greater discrepancy.

The Eating Attitudes Test 26-Items (EAT-26) [121] is a self-report questionnaire assessing disordered eating symptoms. The EAT-26 contains three subscales: dieting, bulimia and food preoccupation, and oral control. Total scores range from 0 to 78, with higher scores indicating increased ED psychopathology. While not a diagnostic tool, a score of 20 or above indicates a high level of concern about dieting, body weight, and problematic behaviours. The EAT-26 demonstrates good psychometric properties, and in the present study internal consistency was good (Cronbach's α = 0.84).

Body composition (total mass, fat mass and lean mass) was analysed via dual energy x-ray absorptiometry (DXA) during PRE16, PRE8 and PRE1. A detailed procedure is discussed in Chapter 6.

A seven-day weighed food record was completed by all participants during PRE16, PRE8, and PRE1. Participants were instructed to document all food, fluid and supplements consumed during the seven day period. Food diaries were analysed using the FoodWorks program (Version 8; Xyris Software Pty, Ltd, Brisbane, Queensland, Australia), and included analysis of reported dietary supplement consumption.

Analysis

Means and standard deviations were calculated for all test parameters. A repeated measures linear mixed model was used to derive estimates of changes in the mean MDDI total score, using an autoregressive first order covariance structure and time as the repeated variable. The model included the fixed factors of time, and the covariates EAT-26 score and years of bodybuilding experience. Where significant changes were detected, post hoc pairwise comparisons with Bonferroni correction were performed. To examine the relationship between MD symptoms and changes in body composition and diet, Pearson correlations were performed between MDDI total score at PRE16, and percent change for body composition and dietary parameters. To explore associations between self-perceived body composition (BIG-O) and measured body composition, Pearson correlations were performed between BIG-O indices of current and ideal fat and muscle, fat and muscle discrepancies, and indices of body composition measured via DXA. Analyses were conducted using IBM SPSS statistics version 22 (IBM SPSS; Chicago, Illinois, USA). Significance was set at $p < 0.05$.

RESULTS

Eleven BB consented to participate in the case series. Two participants withdrew after baseline testing due to withdrawal from competition, with the remaining nine BB (29.0 ± 9.5 years, 177.9 ± 2.5 cm, 83.7 ± 8.9 kg, 6.0 ± 6.6 years bodybuilding participation) included in analyses. Eight of the nine participants were competing at a national level, with the remaining participant competing at an international level.

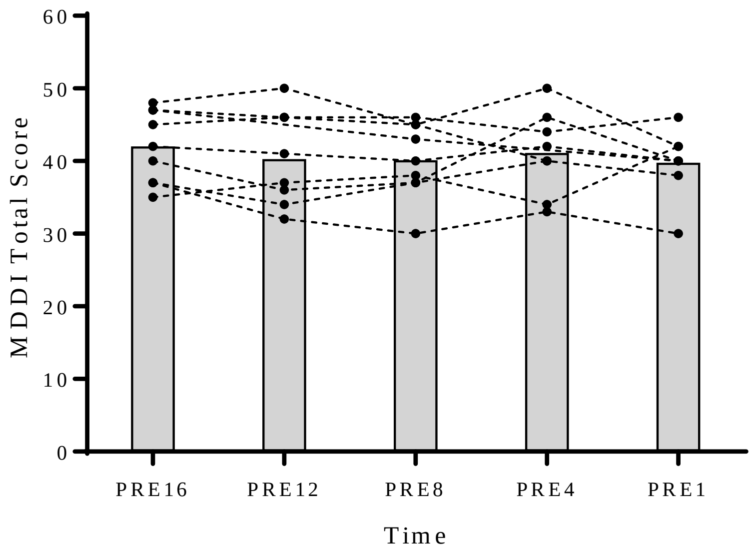
Mean and standard deviation results for MDDI, EAT-26 and BIG-O are presented in Table 7.1. Repeated measures linear mixed modelling adjusting for EAT-26 score and bodybuilding experience found no effect for time on MDDI score, $F(4, 17.641) = 1.417$, $p = 0.269$ (Fig. 7.1a). Similarly, no effect for time on EAT-26 score was found when adjusting for MDDI score and bodybuilding experience, $F(4, 26.152) = 1.152$, $p = 0.355$. Seven of the nine participants scored at or above the EAT-26 cut-off score of 20 for a high level of concern about dieting, body weight, and problematic behaviours at least once during competition preparation (Fig. 7.1b). No effects for time on fat discrepancy index ($F(4, 23.302) = 1.277$, $p = 0.307$), or muscle discrepancy index ($F(4, 25.6) = 0.822$, $p = 0.523$), were found when adjusting for EAT-26 score and bodybuilding experience.

Table 7.1. MDDI, EAT-26, and BIG-O current, ideal and discrepancy index scores, in 9 male natural bodybuilders during 16 weeks of competition preparation.

	PRE16	PRE12	PRE8	PRE4	PRE1
MDDI total	42.0 ± 5.0	40.3 ± 6.5	40.1 ± 5.2	41.1 ± 5.7	39.8 ± 4.6
EAT-26 total	15.7 ± 8.5	16.4 ± 10.2	20.4 ± 11.1	20.3 ± 8.6	20.1 ± 8.1
Current fat	2.33 ± 0.7	1.88 ± 0.6	1.78 ± 0.6	1.5 ± 1.3	1.14 ± 0.4
Current muscle	3.11 ± 0.6	3.13 ± 0.6	3.44 ± 0.5	3.13 ± 0.6	3.29 ± 0.5
Ideal fat	1.44 ± 0.7	1.13 ± 0.3	1.44 ± 0.7	1.13 ± 0.3	1.43 ± 0.5
Ideal muscle	3.78 ± 0.6	3.88 ± 0.6	3.89 ± 0.6	3.75 ± 0.4	3.71 ± 0.5
Fat discrepancy	0.89 ± 0.8	0.75 ± 0.7	0.33 ± 0.9	0.38 ± 1.4	0.56 ± 1.4
Muscle discrepancy	0.67 ± 0.7	0.75 ± 0.4	0.44 ± 0.7	0.63 ± 0.5	0.22 ± 0.7

Data are presented as mean ± SD. PRE16, PRE12, PRE8, PRE4 and PRE1 indicate 16, 12, 8, 4, and 1 week(s) before competition. MDDI, muscle dysmorphic disorder inventory; EAT-26, eating attitudes test 26 items.

a.



b.

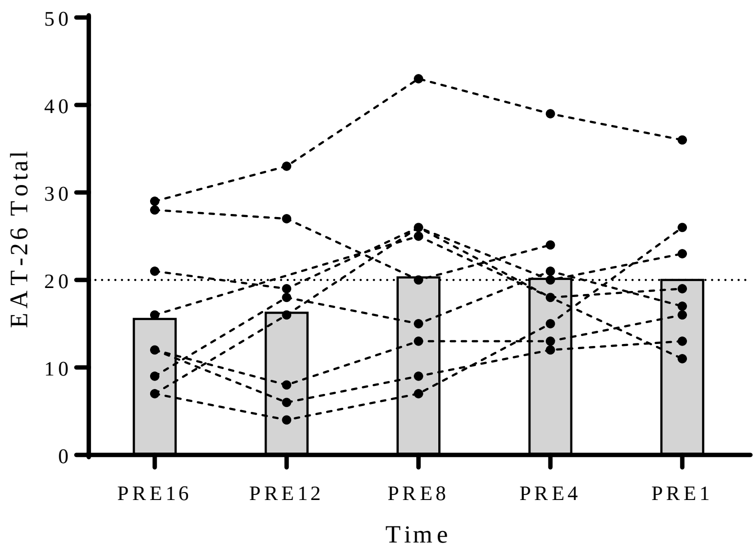


Figure 7.1. **a**. MDDI and **b**. EAT-26 changes during 16 weeks of bodybuilding competition preparation. Enclosed dots indicate individual data; bars indicate mean; horizontal dotted line indicates threshold for a high level of concern about dieting, body weight, and problematic behaviours. PRE16, PRE12, PRE8, PRE4 and PRE1 indicate 16, 12, 8, 4, and 1 week(s) before competition.

Significant correlations were found between PRE16 MDDI score and percent change in energy intake (r = -0.707, p = 0.045), and percent change in fat intake (r = -0.713, p = 0.031), indicating that those scoring higher at baseline on the MDDI showed a greater reduction in energy and fat intake during contest preparation (Fig. 7.2). A significant correlation was found between the change in BIG-O current fat index and the measured change in fat mass (r = 0.84, p = 0.005). No significant correlations were found between changes in BIG-O discrepancy indices and total mass (p > 0.1), fat mass (p > 0.1), or lean mass (p > 0.1).

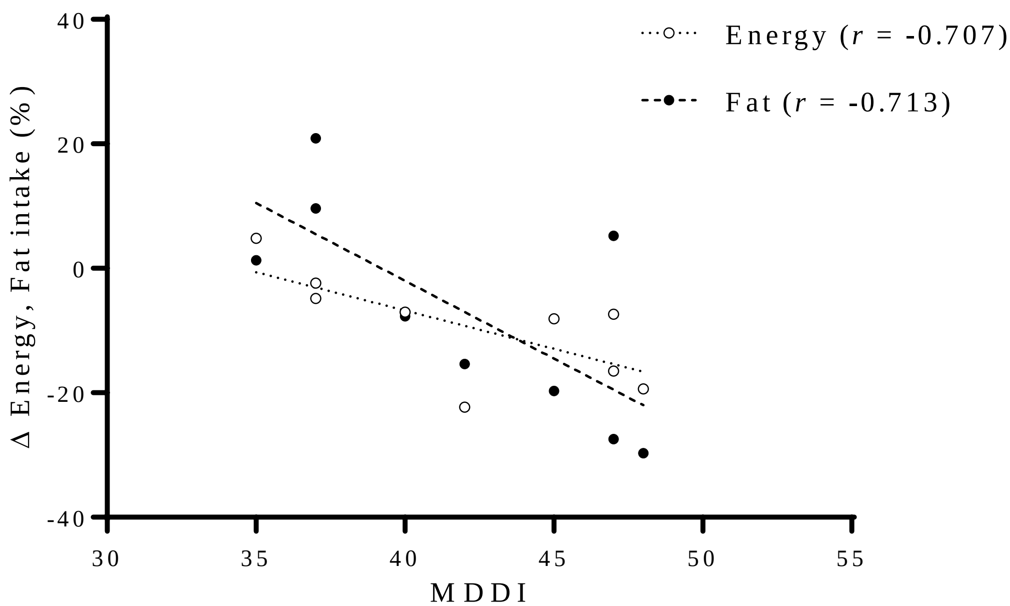


Figure 7.2. Correlations between PRE16 MDDI total score, and the change in energy and fat intake. MDDI, muscle dysmorphic disorder inventory.

Body composition and dietary assessment results are presented in Table 7.2. Repeated measures linear mixed modelling found a significant effect for time on fat mass, $F(2, 15.585) = 12.411$, $p = 0.001$. Post hoc pairwise comparison with Bonferroni correction indicated significant reductions in fat mass from PRE16 to PRE8 ($p = 0.003$), and from PRE16 to PRE1 ($p < 0.001$). Similarly, there was a significant effect for time on total body mass, $F(2, 16.004) = 11.642$, $p = 0.001$. Post hoc comparison indicated significant reductions from PRE16 to PRE8 ($p = 0.021$), PRE16 to PRE1 ($p = 0.001$), and PRE8 to PRE1 ($p = 0.006$). A significant effect for time was found on lean mass, $F(2, 16.001) = 5.419$, $p = 0.016$, with post hoc analysis indicating a significant reduction from PRE8 to PRE1 ($p = 0.022$).

Table 7.2. Body composition and diet composition in 9 male natural bodybuilders during 16 weeks of competition preparation.

	PRE16	PRE8	PRE1
Body mass (kg)	83.7 ± 8.9	81.8 ± 9.1[a]	79.6 ± 9.0[a,b]
Fat mass (kg)	8.8 ± 3.1	6.6 ± 2.4[a]	5.3 ± 2.4[a]
Lean mass (kg)	71.4 ± 8.9	71.8 ± 9.1	70.9 ± 9.1[b]
Energy intake ($kJ \cdot d^{-1}$)	12,585 ± 4,222	11,294 ± 3,192	11,690 ± 3,470
Protein intake ($g \cdot d^{-1}$)	266.9 ± 89.1	245.6 ± 82.0	263.4 ± 101.9
Carbohydrate intake ($g \cdot d^{-1}$)	242.8 ± 100.2	206.0 ± 91.3	232.2 ± 99.8
Fat intake ($g \cdot d^{-1}$)	97.6 ± 58.2	88.7 ± 48.6	79.5 ± 47.8

Data are presented as mean ± SD. [a] indicates significant difference to PRE16, [b] indicates significant difference to PRE8. PRE16, PRE8 and PRE1 indicate 16, 8 and 1 week(s) before competition.

DISCUSSION

The primary purpose of this novel pilot study was to assess the trajectory of MD and ED symptomatology during a period of significant body composition change, that is, during preparation for a natural bodybuilding competition. The BB in this pilot study showed no significant change in MD symptoms during 16 weeks of competition preparation. Similarly, there was no significant change in ED symptoms.

Overall MD symptomatology in this sample of natural BB was moderate, although higher than those reported recently in a similar sample of competitive natural BB (35.2 ± 8.0) [186], and higher than a sample of competitive (38.5 ± 8.0) and non-competitive BB (29.6 ± 6.6) [50]. Importantly, our findings suggest that MD symptoms do not change as a function of body composition, as competition preparation progresses. This suggests a robustness of MD symptomatology despite physiological changes that are intended to better display one's muscularity. An alternative explanation to the preserved symptomatology level is that the MDDI assessment tool may not be sensitive enough to identify changes in MD symptomatology over a short assessment duration.

Previous findings suggest a lability of MD symptomatology, with demonstrable shifts following engagement in resistance training sessions [17]. This fluctuation has been attributed to the short-term increase in muscle size resulting from increased muscle blood flow, in addition to the compensatory property of resistance training in allaying concerns around potential muscle loss [17]. Since bodybuilding contest preparation yields significant reductions in fat mass, it is intuitive to expect this shift in body composition towards the ideal physique to reduce MD symptomatology. However, in this small sample of BB, no such reduction occurred. These findings suggest that attitudinal features of MD may be unrelated to one's actual physical condition. Due to the lack of longitudinal studies currently published, such findings have not previously been reported, however may be explained by the disconnect between actual physique and perceived physique that is central in MD [14]. A primary distinctive characteristic differentiating MD from a non-pathological pursuit of muscularity is a misconceived self-perception of insufficient muscularity. Such a perception drives efforts to increase muscularity as well as leanness [14]. Based on this defining characteristic, a reduction in fat mass shifting body composition towards the ideal lean and muscular physique may not ameliorate the self-determined necessity to maintain an aggressive diet and exercise program in individuals displaying increased MD symptomatology. Thus, the distinct attitudinal features of MD may not be in response to, but rather in spite of, actual physique.

BB in this sample demonstrating higher MD symptomatology at baseline testing subsequently reduced their energy and fat intake to a greater extent than those demonstrating lower symptomatology, further adding to the growing literature relating to MD symptoms and the salience of dietary practices [81,113,115]. Given the noted drive for muscularity as well as leanness in those with MD [93], a greater reduction in energy and fat intake may be suggestive of a desire for increased fat loss, or a greater reluctance to gradually titrate overall body size down to contest condition before the 16-week window prior to contests. This remains an important question for future research endeavours.

Although significant correlations were found between MD symptomatology and subsequent dietary manipulation, no changes in pathological eating practices were identified during competition preparation and recovery. This may reflect the nature of the eating behaviours exhibited by BB. Symptoms of ED have been demonstrated to fluctuate based on engagement in symptomatic behaviour in a clinical population [124]. However, although a strict dietary protocol is maintained by BB in order to achieve competition success, this intense nutrition regimen does not in itself indicate psychopathology. Therefore, engagement in dietary behaviours aimed at achieving competition physique are not likely to produce changes in ED symptoms. The nature of the EAT-26 may also explain the lack of change in ED symptomatology displayed in this study. Items used in the tool may reflect bodybuilding practice, not pathological eating behaviours. Rather than indicating disordered eating habits, the dietary manipulations elicited by BB during preparation for competition are a means of achieving the body composition modification required to reach competition physique.

Limitations of this pilot study include a small sample size (n = 9), necessitating appropriate caution when interpreting these findings. However, this must be considered in conjunction with the noted extreme difficulty in conducting studies of BB during contest preparation. Notwithstanding, a larger sample size would provide greater power to assess changes. The EAT-26 has been previously validated in females, although widely used in male cohorts. However it contains items which may not reflect pathological eating in the bodybuilding context, such as "I am aware of the calorie content of the food I eat." As such, this should be considered when interpreting the ED outcomes. The internal consistency of the MDDI was found to be low in this study, which must be considered when interpreting the results. Nevertheless, this pilot study represents the most rigorous and only longitudinal investigation of MD symptomatology in BB to date, employing an extremely comprehensive battery of assessments. Such a comprehensive assessment protocol may prove difficult to conduct with a larger sample size due to participant restrictions during BB competition preparation, however ongoing research should seek to confirm these results given the importance of this area of research.

CONCLUSION

In this sample of male, natural BB, no significant changes in MD or ED symptomatology were observed, despite significant reductions in total and fat mass during competition preparation. Similarly, no perceptual change in fat and muscle indices were found. Together this suggests that although body composition shifted towards extreme leanness and muscularity in these BB, these changes did not ameliorate concern about their physique. BB displaying increased MD symptomatology may present a disconnect between actual body composition and attitudes around muscularity. Future research should aim to repeat these measures using a larger sample size, including individuals presenting with high MD symptomatology, to confirm these findings.

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CONFLICTS OF INTEREST

HOC receives payments from Sports Dietitians Australia for professional presentations delivered in a continuing education course for Sports Dietitians. All other authors declare no competing or conflicts of interest.

CHAPTER 8.

Conclusions

SUMMARY OF FINDINGS

Participation in the sport of bodybuilding has increased in recent years, and this trend is likely to continue. However, there is limited contemporary research examining the dietary and training practices of male BB, as well as the physiological implications of these practices. Furthermore, there is much to be explored in the area of body image and psychology of BB, specifically in the areas of MD and disordered eating. To date, research into this population has largely focussed on the negative effects of AAS use, from both a physiological and psychological perspective. More recent evidence has emerged of the body composition outcomes achieved during competition preparation, with a small number of studies also documenting hormonal and metabolic adaptations to prolonged negative energy balance during the in-season period, primarily as case studies and small cohorts. Research into bodybuilding and MD has described MD characteristics in BB, and compared symptomatology between BB and other populations. To address the paucity of research in this demographic, this thesis contains a series of studies investigating the dietary strategies employed by male, natural BB, and their effects on body composition and physiology during competition preparation, as well as the psychological implications of competitive bodybuilding.

The primary aims of the studies in this thesis were to:

1. systematically review and compare evidence of MD symptomatology in BB and NBBRT, and identify psychological features associated with MD in these populations;
2. identify correlates of MD symptoms in male, competitive natural BB;
3. identify and describe different dietary and supplement strategies used by experienced natural BB during a competitive season, and their purported rationale;

4. assess the body composition and physiological changes that occur during preparation and recovery from a natural bodybuilding competition; and
5. assess changes in MD and disordered eating symptoms during preparation for a natural bodybuilding competition.

Findings of the systematic review and meta-analysis in Chapter 3 support Hypothesis 1 that BB present greater MD symptomatology than NBBRT. Furthermore, the evidence shows those demonstrating greater MD symptomatology show a greater array of psychological comorbidities including anxiety, depression, perfectionism and low self-esteem. These findings, in particular those psychological comorbidities associated with increased MD symptomatology, may be relevant in delineating between a pathological and non-pathological pursuit of muscularity. The evidence is as yet unable to determine if bodybuilding is a cause of MD, or if the sport of bodybuilding attracts those predisposed to its development. However, these findings suggest that the sport of bodybuilding likely attracts susceptible individuals, while also cultivating advanced MD symptomatology in BB displaying the cluster of psychological features associated with MD. This systematic review and meta-analysis highlights the need for ongoing research, particularly longitudinal research, to further analyse the nature of the relationship between bodybuilding and MD symptoms, particularly in reference to stages of competition preparation and body composition changes.

To examine the association between MD symptomatology and demographic, dietary and training characteristics of male natural BB, the cross-sectional study described in Chapter 4 was conducted to address the second aim of this thesis. Results of this study identified three significant correlates of MD symptomatology. It was demonstrated that disordered eating symptoms were associated with MD symptomatology, thus confirming Hypothesis 2 of this thesis. Similarly, the rate of weight loss during competition preparation was also associated with MD symptomatology. Bodybuilding experience, in the form of years of competing, was negatively associated with MD symptomatology. These findings extend previous research linking ED psychopathology with MD symptomatology, and underscore the salience of disordered eating pathology in presentations of MD symptomatology. This may indicate that the intense nutrition regimen employed by BB does not itself indicate psychopathology, rather it is when eating behaviours become disordered that MD symptomatology may increase. The significant association of rate of weight loss is a key behavioural finding with clinical implications. A rapid rate of weight loss is likely mediated by significant dietary restraint, which further highlights the disordered eating and MD symptomatology link. The association of weight loss rapidity suggests there may be a potential intolerance towards maintaining a reduced body weight, likely due to the noted fear of loss of muscularity in MD. As such, delaying and limiting the weight loss period prior to competition will reduce the period of time spent at a lower body weight, potentially mitigating any anxiety experienced as a result of reduced size and muscularity. The findings of this cross-sectional study further highlight the need for longitudinal research in a bodybuilding sample. Such research may demonstrate temporal changes in MD symptomatology, in particular relative to changes in body composition, engagement in significant dietary and exercise practices, and the effect of competition preparation phase.

Due to the paucity of contemporary evidence of the dietary practices of natural BB, the qualitative study described in Chapter 5 was conducted to address the third aim of this thesis. The findings support experienced competitive BB using dietary strategies predominantly recognised as evidence-based. A high, distributed protein intake was maintained throughout the off-season and in-season to develop and maintain muscle mass, with periodised carbohydrate consumption ensuring effective training sessions. Progressive reductions in energy intake were achieved by moderating carbohydrate and fat consumption. Novel dietary strategies were identified, including the use of a weekly re-feed day to provide a psychological rest, increase muscle glycogen, and purportedly offset declines in metabolic rate associated with prolonged energy restriction. Thus, Hypothesis 3 of this thesis was in part confirmed by the structured and periodised dietary program followed by participants. The second component of Hypothesis 3 was confirmed by identifying questionable strategies used by participants during the peak week period, including sodium and fluid manipulation. These strategies warrant further investigation to describe their safety and efficacy. Finally, the primary sources of nutrition education were identified, and included the internet, other BB and coaches. These findings indicate experienced BB, over the course of their careers, have developed dietary regimens which incorporate primarily evidence-based strategies. Despite this, misinformation and extreme practices remain common in the sport, with novice athletes more vulnerable to these extreme practices, which are widely disseminated on the internet and social media, often from non-reputable sources.

To examine in detail the body composition, physiological and psychological changes which occur during preparation for a bodybuilding competition, the longitudinal study described in Chapters 6 and 7 was conducted. During the 16 week pre-competition period, insignificant reductions in dietary energy intake occurred, with protein intake maintained at a high volume. As was hypothesised (Hypothesis 4 of this thesis), significant reductions in fat mass occurred. However, opposing Hypothesis 4, only small reductions in lean mass were detected. Likely due to the maintenance of lean mass, insignificant changes in RMR occurred during this period. Serum anabolic hormone concentrations, specifically testosterone and IGF-1, were significantly reduced, which may be associated with low energy availability, and confirm the final component of Hypothesis 4. In the four weeks following competition, lean mass, testosterone and IGF-1 all increased towards PRE16 values, which may have reflected cessation of a negative energy balance. These findings demonstrated the success of natural BB in maintaining lean mass whilst reducing fat mass during preparation for competition, which is ultimately the goal during this period. Implementing a high and distributed protein intake appeared to ameliorate reductions in lean mass typically observed during a prolonged period of negative energy balance. Maintaining a high resistance training volume provided an ongoing stimulus for muscle protein synthesis, which, coupled with the high protein intake, produced a cellular environment conducive to limited lean mass loss. These findings add further evidence to the use of an increased protein intake during weight reduction to limit muscle loss.

This study also demonstrated the rigidity of MD symptomatology during a period of significant body composition modification. Despite reducing fat mass with limited change in lean mass, and thus progressing towards the ideal lean and muscular physique, this cohort of natural BB showed no change in MD symptomatology. Additionally, there was no change observed in disordered eating pathology, nor fat and muscle perception indices. These findings oppose Hypothesis 5, and suggest there may be a disconnect between actual body composition and attitudes around muscularity. Another interesting finding from this study was the correlation identified between MD symptomatology and subsequent reductions in energy and fat intake during competition preparation. This adds to the growing literature relating to MD symptoms and the salience of dietary practices.

PRACTICAL IMPLICATIONS

The findings from this thesis have identified previously undocumented dietary practices commonly used by competitive BB. Identifying these practices better equips dietitians to work with BB in prescribing evidence based recommendations, as well as safely manoeuvring through the use of practices for which safety and efficacy is currently unknown. The findings of the qualitative study described in Chapter 5 also highlights the need to promote the role of dietitians to BB. The sample of BB in this study were experienced and followed predominantly evidence-based practices, however the study confirmed there is a large amount of misinformation regarding dietary strategies in the bodybuilding community. Therefore promoting the role of dietitians, in particular their knowledge and skills in body composition assessment and evidence-based guidelines for accrual of lean mass, would be beneficial for BB. This may be particularly important for novice BB who may be more vulnerable to the use of inappropriate strategies.

As demonstrated by the longitudinal study described in Chapter 6, natural BB display a capacity to reduce fat mass to the lower extremities of human body fat levels, whilst concomitantly limiting the loss of lean mass. Preparation practices of these BB highlight the importance of maintaining an increased and distributed protein intake during a period of reduced energy intake, whilst maintaining a high volume of resistance training, in order to stimulate the loss of fat mass and the maintenance of lean mass. As such, these strategies may be considered, along with specific individual dietary requirements, in athletes who target a progressive reduction in fat mass, with minimal reduction of lean mass. Re-feed days documented in the qualitative study described in Chapter 5 were employed by several participants in the longitudinal study. Given the practice is safe, and presents benefits including a psychological recovery and increased training capacity, as well as a potential for improved weight loss efficiency, such a practice may be implemented during a weight reduction period in athletes. Doing so under the supervision of a dietitian may be recommended in order to ensure appropriate modifications to dietary intake, such as carbohydrate and protein volume, are included during the implementation of such a strategy.

The investigations into MD in BB described in Chapters 3, 4 and 7 identified significant practical implications. Firstly, the sport of bodybuilding may attract individuals predisposed to the development of MD, while BB displaying psychological characteristics such as anxiety, depression and low self-esteem may have an increased risk of developing a pathological pursuit of muscularity. Secondly, behavioural characteristics such as pathological eating habits and the rate of weight loss may play important roles in the manifestation of MD symptomatology. Therefore, coaches and clinicians should be observant of these psychological and behavioural characteristics in individuals participating in the sport of bodybuilding, or individuals aiming to commence participation in bodybuilding. Finally, dietary habits adopted by BB during preparation, including increased reductions in energy and fat intake, were found to be associated with increased MD symptomatology. Together with the association of weight loss rapidity, it appears important for coaches, dietitians, and clinicians to monitor the dietary habits and behaviours of BB to ensure their relationship with food and eating does not progress to a pathological state.

STUDY LIMITATIONS

Low statistical power was a primary limitation of the studies described in Chapters 4, 6 and 7. The small sample size in these two studies require consideration when interpreting the non-significant associations, and non-significant changes, respectively. Difficulty with recruitment was the primary factor in limiting the sample size, particularly with the longitudinal study. This was despite use of multiple recruitment strategies, including advertisement on the website and social media pages of the Australasian Natural Bodybuilding Association over a 16 month period, distribution of study flyers at the Australasian Natural Bodybuilding Association national contest, and to a database of BB known from previous research. The significant time commitment required for the study was reported as a common reason for declining participation. Additionally, withdrawal from competition preparation was also reported as a common reason for declining participation and attrition in the longitudinal study. Few studies have examined the body composition and physiology of BB during competition preparation. Difficulty with recruitment may explain the lack of studies, as well as a potential aversion of this demographic to participate in scientific research. Given the significant outcomes, in particular with regards to body composition, more research into this demographic is likely to identify practical strategies capable of being translated into other populations.

Due to limited statistical power the cross-sectional study design of Chapter 4 was unable to identify predictors of MD symptomatology. Furthermore, the significant correlations are unable to provide evidence of causality of these associations. Due to the non-standardised timing of survey completion, variability in reported symptoms may have occurred based on preparation phase and proximity to competition.

The non-significant dietary and physiology changes identified in Chapter 6 may be attributed to the timeline of investigation in this study. An expected reduction in energy, carbohydrate and fat intake between PRE8 and PRE1 testing points was not observed. This may be due to an increased dietary intake in the final week of competition preparation, which was reflected by the non-significant increase in energy and carbohydrate values at this measure, potentially influencing RMR. A modified testing timeline, such as testing two weeks prior to competition, may have detected these expected dietary and physiology changes. Also associated with the study timeline, several participants had commenced their in-season preparation prior to the PRE16 testing point. Therefore this measure may not reflect a true off-season status for these participants. No measure of energy expenditure was conducted in this study which prohibited any calculations of energy balance and energy availability, limiting the interpretation of physiological adaptations which occurred during the testing period.

Dietary intake in the longitudinal study described in Chapters 6 and 7 was measured using seven day weighed food records. Although a diet record is considered the gold standard of dietary assessment, there are limitations inherent to this tool. Significant compliance is required of participants to complete a food record accurately, and compliance is often reduced when recording periods extend longer than four days. Food diaries are time consuming, and require a high level of literacy. Additionally, the burden of completing weighed food records can often lead to changes in dietary intake. However, participants were highly motivated to complete this assessment given the importance of tracking dietary intake for athletic competition, and mostly experienced in using such a tool. Furthermore, participants often consumed the same foods each day, which would reduce participant burden. Therefore the diet assessment data reported in Chapters 6 and 7 is likely accurate and a true reflection of diet for these athletes. In a similar manner, measurement of exercise is limited by the use of a seven day exercise diary. Such a tool is time consuming and places significant burden on participants. Due to this burden, there is a risk that participants report exercise that is programmed to be completed, rather than is actually completed. Wearable activity monitors were initially included in the longitudinal study to reduce such limitations associated with the exercise diaries (see Appendix D), however poor compliance and loss of equipment by participants forced this tool to be withdrawn from the study protocol.

The internal consistency measures of the assessment tools used in study described in Chapter 7 were lower than reported in previous literature. Although these values were considered acceptable due to the exploratory nature of the study, however as such, these psychometric properties must be considered when interpreting the findings of this study.

FUTURE RESEARCH

The outcomes of this thesis have implications for future research in bodybuilding, as well as other athletic populations which require body composition modification. The qualitative study described in Chapter 5 identified novel dietary strategies which have been developed and used in the bodybuilding industry, but as yet have not been empirically investigated. Of particular interest is the use of a weekly re-feed day, which is reported to assist in relieving metabolic adaptations associated with prolonged energy restriction. Hormonal and neuroendocrine responses to these “metabolic rest periods” have been examined in animal models, with promising findings reported. Detailed investigation into the effect of this dietary strategy on RMR and total energy expenditure, weight loss efficiency and ultimately total weight loss is warranted. The response of hormones, in particular the appetite hormones leptin and ghrelin, to this re-feed strategy may help to elucidate its effects on weight loss. Given a primary explanation for ineffective dietary interventions is dietary adherence, re-feed days may present a potential solution to this issue, and thus a further area of exploration in this regard. The inclusion of fluid and sodium manipulation in the peak week period of competition preparation requires specific investigation to determine their safety and efficacy. Examining the effect of these strategies on total body water, urinary output, and hormones such as renin and aldosterone is warranted. Importantly, blood chemistry should be examined in relation to this strategy to determine any potential safety issues.

Due to the modest sample size included in the longitudinal study described in Chapters 6 and 7, more research is required to confirm the findings of these Chapters. In particular, examining the changes in MD symptomatology during competition preparation in a larger sample size, including individuals demonstrating greater MD symptomatology, will provide further evidence of the temporal characteristics of MD. A larger sample size will also allow a more direct assessment of the rate of weight loss and MD symptomatology in BB, based on the outcomes of the cross-sectional study described in Chapter 4.

Including a direct measure of energy expenditure in future research would allow the calculation of energy balance and energy availability. These measures would provide great insight into the physiological and metabolic responses during the bodybuilding competition preparation period, and further explain the outcomes discussed in Chapter 6.

In lean individuals undergoing an energy deficit through diet and exercise, an increased protein intake has been demonstrated to moderate the loss of muscle mass. The BB participating in the longitudinal study described in Chapter 6 consumed a very high and distributed protein intake, which likely contributed to the maintenance of lean mass and subsequently RMR. Future research examining the effect of different doses of protein intake during a prolonged energy deficit, with and without the inclusion of resistance training, would serve to provide more specific guidelines for dietary prescription for BB, and other individuals requiring similar body composition modification.

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APPENDICES

APPENDIX A: SUPPLEMENTARY MATERIAL FOR CHAPTER 3

A1. MEDLINE electronic search strategy

A2. Methodological quality ratings

A1. Electronic search strategy used to search the MEDLINE database with no limits. Similar strategies were used for other electronic information sources, modified to comply with search rules of each database

1. Keyword – Muscle dysmorphia
2. Keyword – Bigorexia
3. Keyword – Reverse anorexia
4. Keyword – Adonis complex
5. Keyword – Manorexia
6. Keyword – Male eating disorder
7. Keyword – Bodybuilding
8. Keyword – Body building
9. Keyword – Bodybuilder
10. Keyword – Body builder
11. Keyword – Strength training
12. Keyword – Weight training
13. Keyword – Resistance training
14. Keyword – Progressive training
15. Keyword – Progressive resistance
16. Keyword – Weight lifting
17. Keyword – Athlete
18. 1 OR 2 OR 3 OR 4 OR 5 OR 6
19. 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17
20. 18 AND 19

A2. Methodological quality ratings

Reference	Hypothesis stated	Outcome described	Subject characteristics described	Principal confounders described	Main findings described	Random variability reported	Actual probability reported	Representative of population	Participating subjects representative	Data dredging	Statistical tests appropriate	Data collection procedures
Boyda et al. (2011)	1	1	1	1	1	1	1	0	0	1	1	1
Gonzalez-Marti et al. (2014)	1	1	0	0	1	0	0	0	0	1	1	1
Lopez-Barajes et al. (2012)	1	1	0	0	1	0	0	0	0	1	1	0
Wolke et al. (2008)	1	1	0	0	1	1	0	0	0	1	1	1
Babusa et al. (2012)	1	1	0	0	1	1	1	0	0	1	1	1
Baghurst et al. (2009)	1	1	1	1	1	1	1	0	1	1	1	1
Cella et al. (2012)	1	1	1	0	1	0	1	0	0	1	1	1
Davies et al. (2011)	1	1	0	0	1	0	0	0	0	1	1	1
Hale et al. (2013)	1	1	0	0	1	1	1	0	0	1	1	1
Lantz et al. (2002)	1	1	0	0	1	1	1	0	0	1	1	1
Santarnecchi et al. (2012)	1	1	0	0	1	1	1	0	0	1	1	1
Skemp et al. (2013)	1	1	1	0	1	1	1	0	0	1	1	1
Soler et al. (2013)	1	1	1	1	1	1	1	1	0	1	1	1
Babusa et al. (2012)	1	1	0	0	1	1	0	0	0	1	1	1
Cafri et al. (2008)	1	1	1	1	1	1	1	0	0	1	1	1
De Lima et al. (2010)	1	1	1	0	1	1	1	0	0	0	1	1
Giardino et al. (2012)	1	1	0	1	1	1	1	0	0	0	0	1
Hildebrandt et al. (2006)	1	1	0	0	1	1	1	0	1	1	1	1
Kanayama et al. (2006)	1	1	0	0	1	1	1	0	0	1	1	0
Kuennen et al. (2007)	1	1	0	0	1	1	1	0	0	1	1	1
Maida et al. (2005)	1	1	0	0	1	1	0	0	0	1	1	0
Nieuwoldt et al. (2015)	1	1	1	0	1	1	1	0	0	0	1	1
Olivardia et al. (2000)	0	1	1	0	1	1	1	0	0	1	1	0
Robert et al. (2009)	1	1	0	0	1	1	0	0	0	1	1	0
Segura-Garcia et al. (2010)	1	1	1	0	1	1	1	0	0	1	1	1
Thomas et al. (2014)	1	1	1	0	1	1	0	0	0	1	1	1
Thomas et al. (2011)	1	1	0	0	1	1	1	0	0	1	1	1

Tod et al. (2014)	1	1	0	0	1	1	0	0	0	1	1	1
Valdes et al. (2013)	1	1	0	0	1	0	0	0	0	0	1	0
Mean	0.97	1	0.38	0.17	1	0.83	0.66	0.03	0.07	0.9	0.97	0.79
SD	0.19	0	0.49	0.38	0	0.38	0.48	0.19	0.26	0.31	0.19	0.41
Median												
Range												

Reference	Groups recruited from same population	Groups recruited over same period of time	Adjustment for confounding	Sufficient power	Groups comparable on confounding factors	Psychological measures appropriate	Clinical & statistical significance reported	Discussion of findings	Study biases and limitations discussed	Source of funding and affiliations described	Total
Boyda et al. (2011)	1	0	0	0	0	1	0	1	1	0	14
Gonzalez-Marti et al. (2014)	1	0	0	0	0	1	0	1	0	0	9
Lopez-Barajes et al. (2012)	0	0	0	0	0	1	1	1	0	0	8
Wolke et al. (2008)	1	0	0	0	0	1	1	1	1	0	12
Babusa et al. (2012)	0	0	0	0	0	1	0	1	0	1	11
Baghurst et al. (2009)	0	0	0	0	0	1	0	1	1	0	14
Cella et al. (2012)	1	0	0	0	0	1	0	1	0	0	11
Davies et al. (2011)	0	0	0	0	0	1	1	1	1	0	10
Hale et al. (2013)	0	0	0	1	0	1	1	1	1	1	14
Lantz et al. (2002)	0	0	0	0	0	1	1	1	1	0	12
Santarnecchi et al. (2012)	0	0	0	0	0	1	1	1	0	1	12
Skemp et al. (2013)	0	0	0	1	0	1	1	1	0	0	13
Soler et al. (2013)	1	0	0	0	0	1	0	1	1	0	15
Babusa et al. (2012)	0	0	0	0	0	1	0	1	1	0	10
Cafri et al. (2008)	1	0	1	1	1	1	1	1	1	1	19
De Lima et al. (2010)	0	1	0	0	0	1	0	1	0	1	12
Giardino et al. (2012)	1	1	0	0	0	1	1	1	1	0	12
Hildebrandt et al. (2006)	0	0	0	1	0	1	1	1	1	0	14
Kanayama et al. (2006)	1	0	1	0	1	1	1	1	1	1	15
Kuennen et al. (2007)	1	0	0	1	0	1	1	1	1	0	14
Maida et al. (2005)	1	0	0	0	0	0	1	1	0	0	9

Nieuwoldt et al. (2015)	1	1	0	0	0	1	1	1	1	0	14
Olivardia et al. (2000)	1	0	0	0	0	0	0	1	1	0	10
Robert et al. (2009)	1	1	0	0	0	1	0	1	1	0	11
Segura-Garcia et al. (2010)	1	0	0	0	0	1	1	1	0	0	13
Thomas et al. (2014)	1	0	0	1	0	1	1	1	1	1	15
Thomas et al. (2011)	1	0	0	0	1	1	1	1	0	0	13
Tod et al. (2014)	1	0	0	0	0	1	1	1	0	1	12
Valdes et al. (2013)	1	0	0	0	0	0	1	1	0	0	7
Mean	0.62	0.14	0.07	0.21	0.1	0.9	0.66	1	0.59	0.28	12.24
SD	0.49	0.35	0.26	0.41	0.31	0.31	0.48	0	0.5	0.45	2.5
Median											12
Range											7-19

SD, standard deviation

APPENDIX B: SUPPLEMENTARY MATERIAL FOR CHAPTER 4

B1. Study protocol for the cross-sectional study

B2. Participant information sheet for the cross-sectional study

B3. Online survey for the cross-sectional study

B4. Advertisement flyer for the cross-sectional study

B1. Study protocol for the cross-sectional study

Correlates of Muscle Dysmorphia Symptomatology in Natural Bodybuilders: Distinguishing factors in the Pursuit of Hyper-Muscularity

Method

A. Study Design

Training Routines, Nutritional Practices, Eating Attitudes and Body Image of Competitive Male Bodybuilders is a cross-sectional study investigating training, nutrition, supplementation practices, and body image and eating attitudes of male, natural bodybuilders.

Data is collected through an anonymous online survey. The survey typically takes 20-30 minutes to complete. The survey is run through an online platform (surveymonkey.com).

B. Participants

Participants will be recruited using the following methods:

- Flyers posted on the ANB official Facebook page, and subsequently "shared" by Facebook users, and bodybuilders.
- Flyers will be distributed at the ANB national contests in October 2015.
- Word of mouth advertisement

Inclusion criteria

- Male, aged 18 years or older
- Natural (drug free) bodybuilders
- Have competed in a natural (drug tested) bodybuilding competition in the past 18 months.

Exclusion criteria

- Have not competed in a natural competition in the past 18 months
- Fitness model division

Study consent

Following the survey link on the study flyer takes potential participants to the opening page of the survey. The opening page of the survey ask questions to confirm eligibility based on the inclusion criteria. Those whom meet eligibility are shown the participant information statement and asked if they consent to participate. Upon providing consent, participants are directed to the remainder of the survey.

C. Study Parameters

The survey contains questions separated into five sections.

1. Training practices.

These questions gather information about the resistance training and aerobic training frequency, duration, intensity and techniques used.

2. Nutritional practices

These questions ask about specific dietary habits. Questions gather information about any special diets participants follow, any foods participants avoid, food preparation habits, and sources of dietary information.

3. Ergogenic aids

This section gathers information about dietary supplements used by participants. Questions ask about the types of supplements used, what stage of the season they are used, and why they are used. This section also gathers information about the use of performance enhancing drugs. Participants can choose to leave these specific questions unanswered.

4. Body image and Eating attitudes

This section contains two validated questionnaires, the Eating Attitude Test 26 items and the Muscle Dysmorphic Disorder Inventory.

4.1 Eating Attitude Test 26

The Eating Attitude Test-26 (EAT-26) is a 26 item questionnaire. The EAT-26 uses a 6-point Likert-type scale for responses, ranging from "never" to "always". The questions are preceded by the statement, "Please respond to each of the following statements. For each question, select the option that most closely describes how the statement applies to you right now."

4.2 Muscle Dysmorphic Disorder Inventory

The Muscle Dysmorphic Disorder Inventory (MDDI) is a brief, 13 item questionnaire. The MDDI uses a 5 point Likert-type scale for responses, ranging from "never" to "always". The questions are preceded by the statement, "Please respond to each of the following statements. For each question, select the option that most closely describes how the statement applies to you right now."

5. Demographic Information

This section gathers basic demographic information including age, height, weight, changes in weight during competition preparation, and bodybuilding experience.

Storage of Data

Data collected from the survey on the online platform will be extracted into Microsoft Excel and stored on the secure, password protected laptop of the researcher.

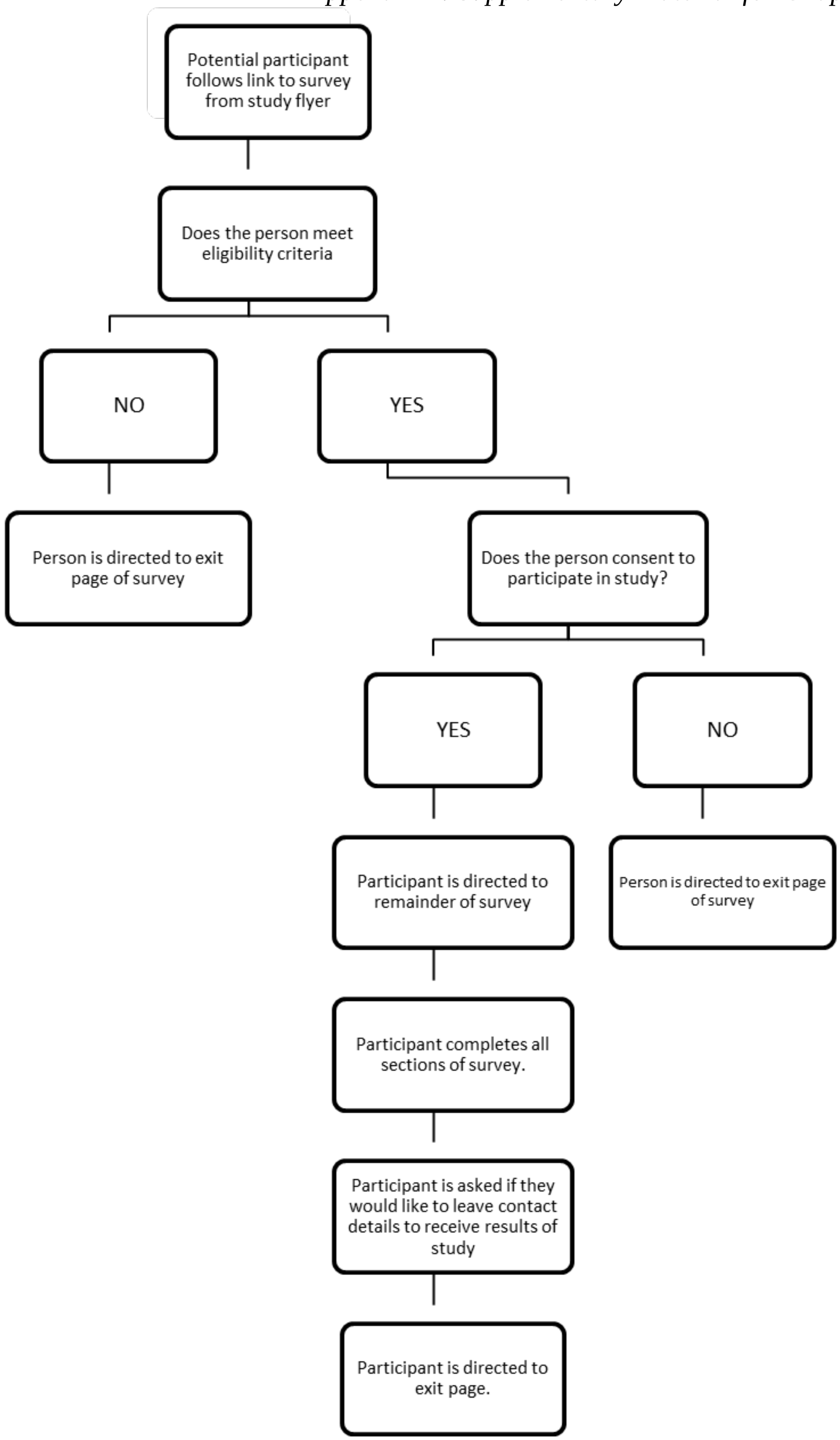

Figure B1. Flowchart of recruitment and study methods

D. Breakdown of Assessment Process

1. Pre-testing

1.1 Participant follows online link to opening page of survey, responds to eligibility questions.

1.2 If eligible, participant is asked to provide consent.

1.3 Participant is directed to data collection questions of survey.

2. Data collection

2.1 Participant completes all five sections of survey.

2.2 Participant provides contact details if they wish to receive results of survey.

2.3 Participant is directed to exit page.

E. Scripts

Initial email script to people expressing interest in study participation

“Hello [insert name],

Thank you for expressing interest in taking part in our study, Training Routines, Nutritional Practices, Eating Attitudes and Body Image of Competitive Male Bodybuilders. Our study involves a short, 20 minute survey conducted online. The study aims to describe the training, nutrition, and supplement practices, and assess body image and eating attitudes of male bodybuilders. Participation is completely voluntary, and responses remain anonymous.

The survey can be accessed using the following link:

https://www.surveymonkey.com/r/8SVBBLK

If you would like further information about the study, please provide a contact number and I will give you a call at a time that suits you. Alternatively please feel free to contact me at your convenience on 0431 363 027.

Kind regards,

Lachlan Mitchell”

F. Collection Forms

Assessment

- Survey questionnaire

B2. Participant information sheet for the cross-sectional study

THE UNIVERSITY OF SYDNEY

Discipline of Exercise and Sports Science
Faculty of Health Sciences

ABN 15 211 513 464

Dr. Helen O' Connor
Chief Investigator

Room H111
Building C43
The University of Sydney
NSW 2006 AUSTRALIA
Telephone: +61 2 9036 7364
Facsimile: +61 2 9351 9204
Email: Helen.oconnor@sydney.edu.au
Web: http://www.sydney.edu.au/

Training Routines, Nutritional Practices, Eating Attitudes and Body Image of Competitive Male Bodybuilders

PARTICIPANT INFORMATION STATEMENT

(1) What is the study about?

This study involves the completion of an anonymous online survey designed to assess the exercise and nutritional habits of bodybuilders who regularly participate in competitions, as well as body image and eating attitudes amongst this population. This study aims to make a valuable contribution to the science of modern bodybuilding, and we hope the information you provide will give insight for sports scientists and sports dietitians into the practicalities of the sport.

As a competitive bodybuilder, you have been invited to participate in this study.

(2) Who is carrying out the study?

The study is being conducted by Dr. Helen O' Connor and Mr. Lachlan Mitchell (PhD candidate) from The University of Sydney, Dr. Matthew Hoon from the Australian Catholic University and Dr. Gary Slater from the University of the Sunshine Coast. This study is likely to form part of Mr. Lachlan Mitchell's doctoral thesis.

(3) What does the study involve/how much time will it take?

Participation in the study will require the completion of an anonymous online survey, which is expected to take approximately 20-30 min.

(4) Is there any risk associated with the study?

As the study is anonymous and survey based, we do not expect any risks associated with the study. A section of the survey will ask if you use performance enhancing drugs. We remind you that this survey is anonymous and your answers will not be identifiable, so we encourage you to answer these questions openly. However, if you do not wish to, you will have the option to skip over these parts. Additionally, certain questions will ask you about body image. However, if you are concerned or experience any distress after completing the questions, please contact the researchers using the details provided to coordinate an appropriate course of action, which may include consultation with a medical professional.

(5) Can I withdraw from the study?

Being in this study is completely voluntary - you are not under any obligation to take the survey. If you do begin the survey and do not wish to complete it, you may withdraw at any time without affecting your relationship with The University of Sydney or the researchers. You can withdraw your responses any time before you have submitted the questionnaire and your data will also not be saved. Once you have submitted it, your responses cannot be withdrawn because they are anonymous and therefore we will not be able to tell which one is yours.

(6) Will anyone else know the results?

All aspects of the study will be strictly confidential and only the researchers will have access to any data collected.

A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. Should you choose to, you may provide your contact details upon completion of the survey, and a summary of the study findings will be provided to you (once available).

(7) Will the study benefit me?

A prize draw will be offered to participants of the study (should they wish to submit their contact details into the draw after completion of the survey), with 5 x $100 Westfield gift cards available. Your name and contact details, stored separately from the survey data, will be used only to contact you if you have won a prize. Winners will be selected randomly following completion of the data collection and the winners will be notified.

(8) Can I tell other people about the study?

Yes and the researchers do encourage you to pass on information to those you believe are suitable for this project. The chief investigator’s contact details are available below should you/they require more information.

(9) What if I require further information about the study or my involvement in it?

If you would like to know more about this study at any stage, please feel free to contact:

Mr. Lachlan Mitchell   lachlan.mitchell@sydney.edu.au   +61 2 9036 7358

Dr. Helen O' Connor helen.oconnor@sydney.edu.au +61 2 9351 9625

(10) What if I have a complaint or any concerns?

Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics Administration, University of Sydney on +61 2 8627 8176 (Telephone); +61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).

Version 2
Date: 21/9/2015

B3. Online survey for the cross-sectional study

Training Routines, Nutritional Practices, Eating Attitudes and Body Image of Competitive Male Bodybuilders

Welcome to the online survey about bodybuilding training, nutrition and body image; a study run by researchers from the University of Sydney, University of the Sunshine Coast and the Australian Catholic University. Before you continue:

☐ Are you Male
☐ Over 18 yrs
☐ Have you participated in a bodybuilding contest in the last 18 months
☐ Compete naturally (i.e. you have not used any prohibited substances in the past 24 months)

- ➔ **If ≥1 not ticked, direct to exclusion page (please see final page)**
- ➔ **If ALL TICKED, proceed below**

Based on your submitted information, you are eligible to participate in our survey. Before you do, we ask you to kindly read the below information detailing the requirements of the study and your legal rights as a participant; which may help you decide if you wish to take part in the research.

PARTICIPANT INFORMATION STATEMENT

(11) What is the study about?

This study involves the completion of an anonymous online survey designed to assess the exercise and nutritional habits of bodybuilders who regularly participate in competitions, as well as body image and eating attitudes amongst this population. This study aims to make a valuable contribution to the science of modern bodybuilding, and we hope the information you provide will give insight for sports scientists and sports dietitians into the practicalities of the sport.

As a competitive bodybuilder, you have been invited to participate in this study.

(12) Who is carrying out the study?

The study is being conducted by Dr. Helen O' Connor and Mr. Lachlan Mitchell (PhD candidate) from The University of Sydney, Dr. Gary Slater from the University of the Sunshine Coast and Dr. Matthew Hoon from the Australian Catholic University. This study is likely to form part of Mr. Lachlan Mitchell's doctorial research.

(13) What does the study involve/how much time will it take?

Participation in the study will require the completion of an anonymous online survey, which is expected to take approximately 20-30 min.

(14) Is there any risk associated with the study?

As the study is anonymous and survey based, we do not expect any risks associated with the study. A section of the survey will ask if you use performance enhancing drugs. We remind you that this survey is anonymous and your answers will not be identifiable, so we encourage you to answer these questions openly. However, if you do not wish to answer these items, you will have the option to skip over these parts. Additionally, certain questions will ask you about body image. However, if you are concerned or experience any distress after completing the questions, please contact the researchers using the details provided to coordinate an appropriate course of action, which may include consultation with a medical professional.

(15) Can I withdraw from the study?

Being in this study is completely voluntary - you are not under any obligation to take the survey. If you do begin the survey and do not wish to complete it, you may withdraw at any time without affecting your relationship with The University of Sydney or the researchers. You can withdraw your responses any time before you have submitted the questionnaire and your data will also not be saved. Once you have submitted it, your responses cannot be withdrawn because they are anonymous and therefore we will not be able to tell which one is yours.

(16) Will anyone else know the results?

All aspects of the study will be strictly confidential and only the researchers will have access to any data collected.

A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. Should you choose to, you may provide your contact details upon completion of the survey, and a summary of the study findings will be provided to you (once available).

(17) Will the study benefit me?

A prize draw will be offered to participants of the study (should they wish to submit their contact details into the draw after completion of the survey), with 5 x $100 Westfield gift cards available. Your name and contact details, stored separately from the survey data, will be used only to contact you if you have won a prize. Winners will be selected randomly following completion of the data collection and the winners will be notified.

(18) Can I tell other people about the study?

Yes and the researchers do encourage you to pass on information to those you believe are suitable for this project. The chief investigator's contact details are available below should you/they require more information.

(19) What if I require further information about the study or my involvement in it?

If you would like to know more about this study at any stage, please feel free to contact:

Mr. Lachlan Mitchell lachlan.mitchell@sydney.edu.au +61 2 9036 7358
Dr. Helen O' Connor helen.oconnor@sydney.edu.au +61 2 9351 9625

(20) What if I have a complaint or any concerns?

Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics Administration, University of Sydney on +61 2 8627 8176 (Telephone); +61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).

Consent

By giving your consent to take part in this study you are telling us that you:

- ✓ Understand what you have read.
- ✓ Agree to take part in the research study as outlined above.
- ✓ Agree to the use of your personal information as described.

☐ Yes, I consent to participate in the study → **GOES TO NEXT SECTION**
☐ No, I do not agree to participate in the study → **EXIT PAGE (see final page)**

Bodybuilding Survey

The participant of this survey MUST have competed in a bodybuilding contest.

Your answers and experiences are important to us.

To help us read your answers, please type in your response where indicated

Please put a cross in the appropriate box(es) ☒ Yes ☐ No

Resistance Training Practices

What is your maximum bench press lift (1RM)?	__________ kg	☐ Unsure				
What is your maximum squat lift (1RM)?	__________ kg	☐ Unsure				
Do you perform whole body training sessions or split routines?	☐ Split	☐ Whole body	☐ Both			
During your off-season, how many resistance training sessions do you perform per week and what is the average time of each session?	Sessions per week	☐ 2-3	☐ 4-5	☐ 6-7	☐ 8-9	☐ +10
	Time per session (mins)	☐ <20 ☐ 50-60	☐ 20-30 ☐ 60-90	☐ 30-40 ☐ +90	☐ 40-50	
During your in-season, how many resistance training sessions do you perform per week and what is the average time of each session?	Sessions per week	☐ 2-3	☐ 4-5	☐ 6-7	☐ 8-9	☐ +10
	Time per session (mins)	☐ <20 ☐ 50-60	☐ 20-30 ☐ 60-90	☐ 30-40 ☐ +90	☐ 40-50	

Do you use any of the listed advanced overload techniques in your training?

☐ Giant sets	☐ Super sets	☐ Forced reps
☐ Negatives	☐ 21's	☐ Timed reps
☐ Partial reps	☐ Pre exhaustion sets	☐ Post exhaustion sets
☐ Pyramids	☐ Breakdowns	☐ None
☐ Other ______________________________		

If yes, when do you perform them (e.g. in-season, off-season, high volume week, low volume week, peak-week) and for what exercises?

____
____
____
____

What is the general training intensity you use during the off-season?	Exercises per muscle group	☐ 1	☐ 2-3	☐ 4-5	☐ ≥6	
	Sets per exercise	☐ 1-2	☐ 3-4	☐ 5-6	☐ ≥7	
	Reps to failure per set (Repetition Max)	☐ 1-3	☐ 4-6	☐ 7-9	☐ 10-12	☐ 13-15
	Recovery time between sets (secs)	☐ 30-60	☐ 61-120	☐ 121-180	☐ 181-300	☐ ≥ 301

Do you modify your training during the off-season by lifting heavier loads with lower repetitions (1-5RM)?	☐ Yes	☐ No
Do you periodise your training during the off-season?	☐ Yes	☐ No

If yes, please describe how:

____
____
____
____
____
____
____

What is the general training intensity you use during the in-season?	Exercises per muscle group	☐ 1	☐ 2-3	☐ 4-5	☐ ≥6	
	Sets per exercise	☐ 1-2	☐ 3-4	☐ 5-6	☐ ≥7	
	Reps to failure per set (RM)	☐ 1-3	☐ 4-6	☐ 7-9	☐ 10-12	☐ 13-15

	Recovery time between sets (secs)	☐ 30-60	☐ 61-120	☐ 121-180	☐ 181-300	☐ ≥ 301

When do you start your in-season (weeks before the competition)? ________weeks

Aerobic (Cardio)Training Practices

Do you perform any aerobic exercise in your training? ☐ Yes ☐ No

Describe the aerobic exercise that you perform below:

	Off-Season			In-Season		
Exercise Type	☐ Walking ☐ Jogging/running ☐ Cycling ☐ Swimming ☐ Rowing ☐ Cross trainer ☐ Skipping ☐ Boxing ☐ Other______			☐ Walking ☐ Jogging/running ☐ Cycling ☐ Swimming ☐ Rowing ☐ Cross trainer ☐ Skipping ☐ Boxing ☐ Other_____		
Sessions per week	☐ 1-2	☐ 2-4	☐ ≥ 5	☐ 1-2	☐ 2-4	☐ ≥ 5
Time per session (mins)	☐ 10-20 ☐ 20-30 ☐ 30-45 ☐ > 45			☐ 10-20 ☐ 20-30 ☐ 30-45 ☐ > 45		

Perceived intensity of exercise	☐ Low (6-11/20) ☐ Moderate (12-15/20) ☐ High (16-20/20)	☐ Low (6-11/20) ☐ Moderate (12-15/20) ☐ High (16-20/20)

Do you ever perform fasted cardio sessions?
☐ No
☐ Yes: ________ times a week

Where do you get your training advice from? (You may select more than one)

☐ Other bodybuilders
☐ Online blog/forum
☐ Family/friends
☐ Magazines
☐ Other: ________________
☐ Coach
☐ Scientific publications
☐ Health food store
☐ Personal trainer
☐ Exercise scientist
☐ Doctor

Dietary practices

Food intake

Do you follow any special diets? (You may select more than one)

- ☐ High protein
- ☐ High-carb
- ☐ Vegan
- ☐ Paleo
- ☐ Low-Carb
- ☐ Vegetarian
- ☐ Atkins
- ☐ Carb-cycling
- ☐ Lacto-ovo vegetarian
- ☐ No sugar
- ☐ Carb re-feeding
- ☐ Low-calorie
- ☐ High-calorie
- ☐ Salt reduced
- ☐ Gluten free
- ☐ Dairy free
- ☐ Food allergy/intolerance. Please describe:_____________

☐ Other:____

☐ I do not follow a special diet

If you indicated that you do follow a special diet, could you please explain why you are following it?:

____

____

____

Do you avoid/limit quantity any of the following food groups (grains, cereals, dairy, fats, oils, starchy vegetables)? (You may select more than one)

- ☐ Bread
- ☐ Grains / cereals
- ☐ Dairy (e.g. milk, cheese, yoghurt)
- ☐ Fats / Oils
- ☐ Starch vegetables (e.g. potato, sweet potato
- ☐ Fruits
- ☐ Red meat (e.g. beef lamb)
- ☐ White meat (e.g. chicken, turkey, pork)
- ☐ Seafood (e.g. fish, prawns, crab)
- ☐ Treats e.g. cakes/lollies
- ☐ Alcohol
- ☐ Fast food

☐ I do not generally restrict any food groups

☐ Other:____

If you indicated that you avoid certain food groups, could you please explain why you do so?
____
____
____

How often do you eat out/takeaway?
During off-season____________ times per month
During in-season________________ times per month

Who most often prepares your food?
☐ Only me ☐ Partner ☐ Family member
☐ Special food service ☐ Restaurants

Do you weigh your food in the off season? ☐ Never ☐ Some of the time ☐ Most of the time ☐ All the time

Do you weigh your food during the in-season? ☐ Never ☐ Some of the time ☐ Most of the time ☐ All the time

Where do you get your dietary advice from? (You may select more than one)
☐ Coach ☐ Other body builders
☐ Dietitian ☐ Exercise Scientist
☐ Doctor ☐ Personal trainer
☐ Alternative medical practitioner (e.g. naturopath)
☐ Family/friends ☐ Online blog/forums
☐ Scientific publications ☐ Magazines
☐ Health food store ☐ Supplement Store
☐ Other: ________________

Dietary Supplements

Do you use supplements?	☐ Yes	☐ No

What supplements do you use during the off-season, and in-season? (Tick appropriate boxes)

	Off-season	In season
Protein powders		
Whey		
Casein		
Amino Acids		
Other		
Pre workouts		
Caffeine		
Creatine		
Beta-alanine		
Other		
Herbal Remedy		
Testosterone boosters		
Other		
General		
Vitamins		
Mineral		
Glucosamine		
Glutamine		
HMB		
BCAA		
Omega 3/fish oil		
Carnitine		
Arginine		
d-aspartic acid		
Probiotics		
Other		

If you indicated ‘other’ above, could you please list other supplements you may take:

____

____

Why do you take supplements?

- ☐ Aid training
- ☐ Improve muscle size
- ☐ Avoid nutrient deficiencies
- ☐ Meal replacement
- ☐ Fat loss
- ☐ Boost recovery

- ☐ Feel better
- ☐ Stay healthy
- ☐ Other_________________

Have you ever used performance enhancing drugs?	☐ Yes	☐ No	☐ Prefer to not disclose

What drugs did you use? ____
____
____

Why did you use these drugs? ____

Eating Attitudes Test 26 Items (EAT-26)

Instructions: Please respond to each of the following statements. Circle the response choice that best describes you

	Never	Rarely	Some times	Often	Very often	Always
1. I am terrified about being overweight	1	2	3	4	5	6
2. I avoid eating when I am hungry	1	2	3	4	5	6
3. I find myself preoccupied with food	1	2	3	4	5	6
4. I have gone on eating binges where I feel that I may not be able to stop	1	2	3	4	5	6
5. I cut my food into small pieces	1	2	3	4	5	6
6. I am aware of the calorie content of foods that I eat	1	2	3	4	5	6
7. I particularly avoid foods with high carbohydrate content	1	2	3	4	5	6
8. I feel that others would prefer I ate more	1	2	3	4	5	6
9. I vomit after I have eaten	1	2	3	4	5	6
10. I feel extremely guilty after eating	1	2	3	4	5	6
11. I am preoccupied with a desire to be thinner	1	2	3	4	5	6
12. I think about burning up calories when I exercise	1	2	3	4	5	6
13. Other people think that I am too thin	1	2	3	4	5	6
14. I am preoccupied with the thought of having fat on my body	1	2	3	4	5	6
15. I take longer than others to eat meals	1	2	3	4	5	6

16. I avoid foods with sugar in them	**1**	**2**	**3**	**4**	**5**	**6**
17. I eat diet foods	**1**	**2**	**3**	**4**	**5**	**6**
18. I feel that food controls my life	**1**	**2**	**3**	**4**	**5**	**6**
19. I display self-control around food	**1**	**2**	**3**	**4**	**5**	**6**
20. I feel that others pressure me to eat	**1**	**2**	**3**	**4**	**5**	**6**
21. I give too much time and thought to food	**1**	**2**	**3**	**4**	**5**	**6**
22. I feel uncomfortable after eating sweets	**1**	**2**	**3**	**4**	**5**	**6**
23. I engage in dieting behaviour	**1**	**2**	**3**	**4**	**5**	**6**
24. I like my stomach to be empty	**1**	**2**	**3**	**4**	**5**	**6**
25. I enjoy trying new rich foods	**1**	**2**	**3**	**4**	**5**	**6**
26. I have the impulse to vomit after meals	**1**	**2**	**3**	**4**	**5**	**6**

Body Image

Instructions: Please respond to each of the following statements. Circle the response choice that best describes you

	Never	Rarely	Sometimes	Often	Always
1. I think my body is too small	1	2	3	4	5
2. I wear loose clothing so that people cannot see my body	1	2	3	4	5
3. I hate my body	1	2	3	4	5
4. I wish I could get bigger	1	2	3	4	5
5. I think my chest is too small	1	2	3	4	5
6. I think my legs are too thin	1	2	3	4	5
7. I feel like I have too much body fat	1	2	3	4	5
8. I wish my arms were bigger	1	2	3	4	5
9. I am very shy about letting people see me with my shirt off	1	2	3	4	5
10. I feel anxious when I miss one or more workout days	1	2	3	4	5
11. I pass up social activities (eg. Watching football games, eating dinner, going to see a movie) with friends because of my workout schedule	1	2	3	4	5
12. I feel depressed when I miss one or more workout days	1	2	3	4	5
13. I pass up chances to meet new people because of my workout schedule	1	2	3	4	5

Background Information

What is your age? ________ yrs

What is your height? ______________cm

What is your current weight? _____________ kg

How does your weight vary over the season:
Stage weight _________
Max weight ________

How many weeks before comp do you commence cutting? _____________ wks

At what age did you start lifting weights? ________________

How many years have you been competing in bodybuilding? ___________________ yrs

Why did you begin bodybuilding?

- ☐ Always interested
- ☐ Approached by another bodybuilder
- ☐ To increase muscle/body weight
- ☐ To lose weight
- ☐ To improve body image
- ☐ To improve self esteem
- ☐ Negative comments about my weight
- ☐ To get fit
- ☐ Other ____

What types of bodybuilding competitions do you competed in? ☐ Natural ☐ Amateur ☐ Professional

What category do you compete in? _______________________

How many competitions have you competed in and what is your best result?

No. of Competitions: ________________________

Best Result:________________________________

When did you last compete in a bodybuilding competition? ___________ months ago

Thank you!

Thank you for your participation in this study. Your answers are highly valued by the researchers and we hope the data collected can provide us with some informative insight into the sport.

Do you wish to enter the draw to win a $100 Westfield gift voucher? If so, please provide your contact details below. The winners will be randomly drawn and notified through the details provided. Please note your personal details will be separated from your responses to ensure your responses remain anonymous

Would you be interested in receiving a summary of the findings from this study? If so, please provide your contact details below.

Would you be interested in participating in other bodybuilder research projects conducted by the University of Sydney or the University of the Sunshine Coast?

If so, please provide your name and contact details below, and should a suitable project come up, the research team will contact you:

Thank you once again for your participation in our study.

Kind regards,

The Research Team

Exclusion Page

Thank you for taking interest in the study. Unfortunately, you are outside of the targeted population we wish to investigate. As we, the researchers, are only just beginning to explore the world of bodybuilding, we may choose to investigate other areas and individuals in future projects. In this case, we encourage you to keep an eye out for any studies that may suit you.

Kind regards,
The Research Team

Exit page

Thank you for taking interest in our study. If you have chosen not to participate in our study as you require more information, please feel free to contact the researchers:

Mr. Lachlan Mitchell	lachlan.mitchell@sydney.edu.au	+61 2 9036 7358
Dr. Helen O' Connor	helen.oconnor@sydney.edu.au	+61 2 9351 9625

Kind regards,
The Research Team

Version 2
Date: 29/5/2015

B4. Advertisement flyer for the cross-sectional study

THE UNIVERSITY OF SYDNEY

The Art & Science of Modern Bodybuilding

University researchers are looking to study the diet and training strategies used by competitive natural bodybuilders. The study will also gather data on eating attitudes and body image.

Participants can enter the draw to win one of five

$100 GIFT CARDS

What is involved?

- Complete an anonymous 20-30 min online survey

Participants need to be:

- Male, over 18 years of age
- Competed in at least one natural bodybuilding competition within the last 18 months

If you are interested and eligible, please visit:
https://www.surveymonkey.com/r/8SVBBLK

For further information, please contact:
Lachlan Mitchell: lachlan.mitchell@sydney.edu.au | (02) 9036 7358

VERSION 1, August 2015

APPENDIX C: SUPPLEMENTARY MATERIAL FOR CHAPTER 5

C1. Study protocol for the qualitative study

C2. Participant information sheet for the qualitative study

C3. Participant consent form for the qualitative study

C4. Interview script for the qualitative study

C5. Advertisement flyer for the cross-sectional study

C6. Consent form to advertise study for recruitment purposes

C1. Study protocol for the qualitative study

Do Bodybuilders Use Evidence Based Nutrition Strategies to Manipulate Physique?

Method

A. Study Design

The Modern Bodybuilder: Nutrition and Training Strategies is a cross-sectional study investigating nutrition, supplementation and training habits of experienced male, "natural" bodybuilders during preparation for competition.

Data collection takes place during a one-off in-depth interview. Interviews occur either in person, at the University of Sydney Cumberland Campus, or over the phone. Interviews typically take 90 minutes to complete.

B. Participants

Participants will be recruited using the following methods:

- Flyers posted on the ANB official Facebook page, and subsequently "shared" by Facebook users.
- Flyers distributed to bodybuilders from previous studies
- Word of mouth advertisement

Inclusion criteria

- Male, aged 18 years or older
- Natural (drug free) bodybuilders, competing in the bodybuilding division of drug-tested bodybuilding federations.
- Five or more years bodybuilding experience, with competition experience at either national or international bodybuilding contests

Exclusion criteria

- Less than five years' experience
- No national or international competition experience
- Fitness model division

C. Study Parameters

The interview is a semi-scripted interview, with questions asking for information about topics relevant to bodybuilding preparation. The script has been designed to allow probing for further information. The topics of questions include demographic information and bodybuilding experience, training/exercise, dietary intake, dietary supplements, performance enhancing drugs, and sources of bodybuilding information.

Participants are free to decline to answer any question or section of questions, and can finish the interview at any time.

Participants taking part in the interview face to face are to present to the campus at the designated time. The interview is to be conducted in H111. Participants taking part in the interview over the phone are asked to dial in to the conference call using the number provided (Optus ExecutiveMEET).

The interview will be recorded to produce an mp3 file. The interview recording will be uploaded to a secure transcription service website (Way With Words) whose staff transcribe the interviews. Transcribed interviews will be de-identified for name, and other identifying features, and sent back to participants for verification and correction. Participants may make changes to transcripts to correct transcriber error, replace what was said with the intended meaning, or further de-identify themselves. Field notes will also be taken by the researcher to capture information such as details not spoken (e.g. tone, body language) or comments/information passed on outside of the recording. These documents will be included as data in the analysis.

Analysis of In-depth Interview

As categorisation and coding of data proceed, underlying contextual themes will emerge through talk on the topics. The data will be analysed inductively. Identification of themes that recur through and across interviews will be achieved by a process of reading, coding, code category refinement, rereading and code checking, and analysis of developing concepts. To assist in organising ideas from the unstructured data, pieces of data within the text of each interview will be coded using specialised software (NVivo 10.0, QSR International Pty. Ltd., Doncaster, Australia, 2012). Coding will be done in duplicate.

Storage of Data

Interview recordings will be stored on the secure, password protected laptop of the researcher. Field notes taken during the interviews will be stored in a locked cabinet draw, in the locked office of the researcher, located in H111.

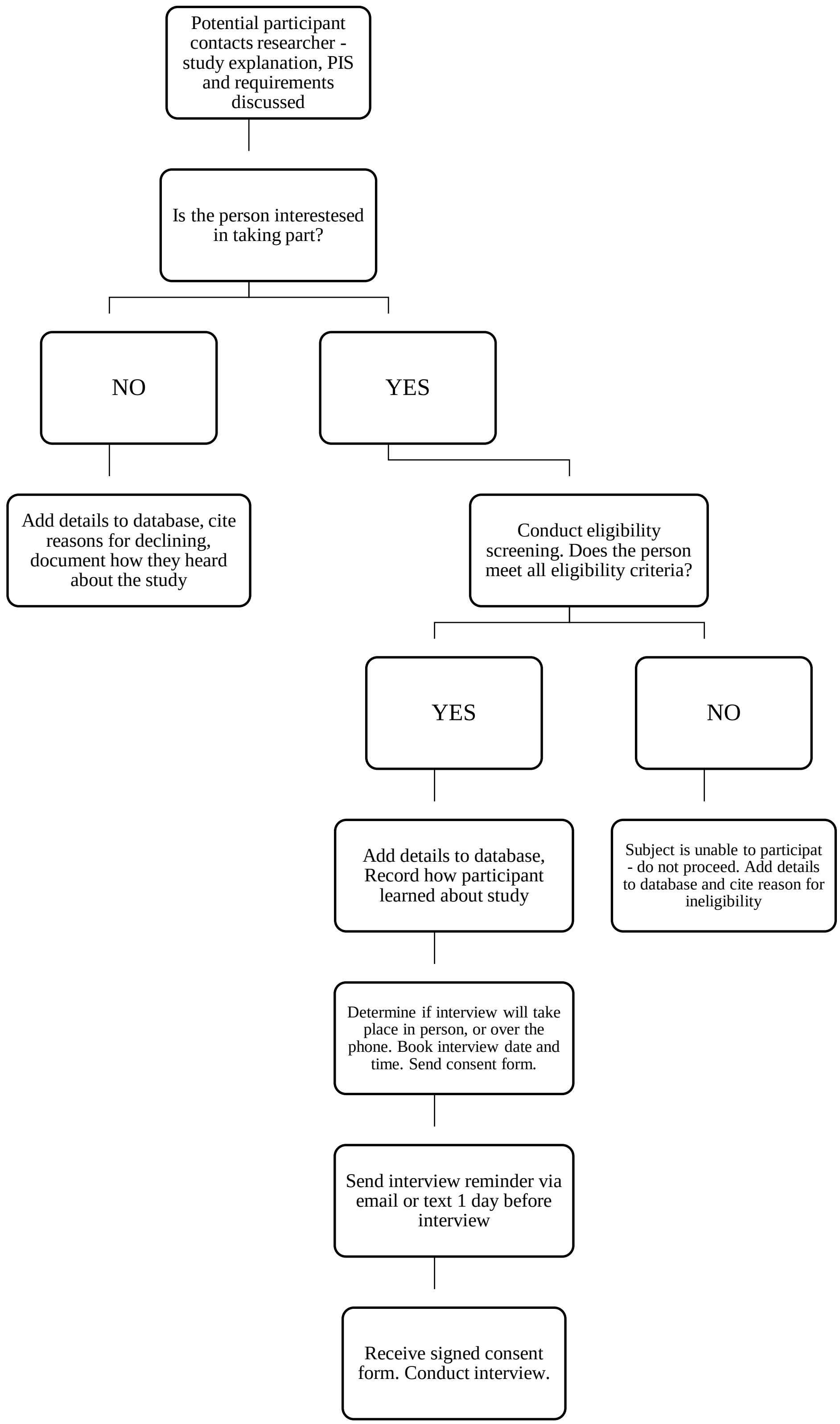

Figure C1. Flowchart of recruitment and study methods

D. Breakdown of Assessment Process

1. Pre-testing

1.1 Provide information to potential participants via phone or email. Document all enquiries in the recruitment tracking sheet.
1.2 Screen participant, document outcomes in participant tracking sheet.
1.3 If eligible, book in interview time and date.
1.4 Send participation information statement if not done so during initial contact, via email or post. Ask participant to read carefully and ask any questions before the interview begins.
1.5 If interview is to be conducted over the phone, also send a consent form to be signed by participant.
1.6 Instruct the participant to present to the campus at the designated time if interview is to be conducted in person. Provide participant with consent form to sign. Provide participant with conference call number if interview is to be conducted over the phone.

2. Interview
2.1 Ensure signed consent form has been returned either via email, or signed in person.
2.2 Begin interview by reminding participant of study details, that they are free to decline to answer any question or section of questions. Also remind participant that the interview is being recorded.
2.3 Conduct interview by following script. Probe for further information as necessary.

E. Scripts

Initial email script

"Hello [insert name],

Thank you for expressing interest in taking part in our study, The Modern Bodybuilder: Nutrition and Training Strategies. Our study will involve a one-off, in-depth interview, which can be conducted in person on campus, or over the phone. The study aims to describe the nutrition, supplement and training practices of male, competitive, natural bodybuilders. The interview will take approximately 90 minutes to complete. Two researchers will be present for the interview. The interview will be recorded and transcribed to then be analysed. I have attached an information statement which gives a thorough run down of the study.

We would love to have you involved. If you would like further information or would like to proceed with taking part, the next step is to conduct a brief telephone screen (2 minutes) to check the eligibility criteria is met. If so, please let me know the best time and number to contact you on, and I will give you a call. Alternatively please feel free to contact me at your convenience on 0431 363 027.

Kind regards,

Lachlan Mitchell”

F. Collection Forms

Pre assessment

- Participant consent form
- Consent to advertise study on website and Facebook page

Assessment

- Interview script

C2. Participant information sheet for the qualitative study

THE UNIVERSITY OF SYDNEY

Discipline of Exercise and Sport Science
Exercise, Health and Performance
Research Group
Faculty of Health Science

ABN 15 211 513 464

Dr Helen O'Connor
SENIOR LECTURER, DISCIPLIINE OF EXERCISE & SPORT SCIENCE

Room H106
C42 Cumberland Campus
The University of Sydney
75 East St Lidcombe
NSW 2141 AUSTRALIA
Telephone: +61 2 9351 9625
Facsimile: +61 2 9351 9204
Email:
helen.oconnor@sydney.edu.au
Web: http://sydney.edu.au/health-sciences/

THE MODERN BODYBUILDER: NUTRITION AND TRAINING STRATEGIES

PARTICIPANT INFORMATION STATEMENT

(1) What is the study about?

You are invited to participate in a study titled The Modern Bodybuilder: Nutrition and Training Strategies. The overall aim of the study is to describe the nutrition, supplement and training strategies used by natural bodybuilders in preparation for competition. We are recruiting open division male and female bodybuilders with 5 or more years bodybuilding experience who are willing to participate in the study.

(2) Who is carrying out the study?

The study is being conducted at The University of Sydney by the following researchers:

- Dr Helen O'Connor, Faculty of Health Sciences, The University of Sydney
- Dr Daniel Hackett, Faculty of Health Sciences, The University of Sydney
- Dr Stephen Cobley, Faculty of Health Sciences, The University of Sydney
- Dr Janelle Gifford, Faculty of Health Sciences, The University of Sydney

- Dr Gary Slater, Faculty of Science, Health, Education and Engineering, University of Sunshine Coast
- Mr Lachlan Mitchell (Masters Student), Faculty of Health Science, The University of Sydney

(3) What does the study involve?

If you agree to take part in this study you will be asked to sign the Participant Consent Form. All participants will be invited to participate in a one on one interview, **<u>or over the phone</u>,** interview with one of the researchers.

Interviews will take place in person **<u>or via a phone call</u>**. All **<u>face to face</u>** interviews will take place at either University of Sydney, Cumberland Campus, 75 East Street Lidcombe, NSW 2141; or University of Sydney, Faculty of Health Science Offices, Camperdown Campus, Parramatta Rd, Camperdown, NSW 2006

The interview will gather information regarding the nutrition, supplementation and exercise strategies used by natural bodybuilders during different stages of preparation for bodybuilding contests. Participants will be free to decline to answer any question for which they do not feel comfortable to respond. Interviews will be taped by researchers, and later transcribed by a transcription service. Participant confidentiality will be maintained and all interviews will be de-identified.

Information about nutrition, supplement and training strategies obtained during the interviews may be used to help develop a second research project involving bodybuilders. You will not be required to participate in this second project.

(4) How much time will the study take?

The interview will take approximately 60-90 minutes to complete.

(5) Can I withdraw from the study?

Being in this study is completely voluntary – you are not under any obligation to consent and, if you do consent, you can withdraw at any time without affecting your relationship with The University of Sydney. Any data collected prior to your withdrawal will be destroyed.

(6) Will anyone else know the results?

Participant confidentiality will be maintained by the assignment of a study ID number. This will be used on all data collection sheets. Records from the study that identify participants by name will be treated as strictly confidential and will be kept in a locked filing cabinet in a locked office away from all other study data. Only staff directly involved in the study will have access to participate records. If the results of this study lead to publication in a research thesis, scientific journal or are represented at scientific meetings, individual participants will not be identified by name.

(7) Will the study benefit me?

Yes. At the conclusion of the interview a qualified dietitian will be available for up to 20 minutes for participants to ask questions concerning dietary practices.

(8) Can I tell other people about the study?

Yes, if you know a male or female natural bodybuilder who has competed at, or is intending to compete at, a bodybuilding contest please tell them about this study.

(9) What if I require further information about the study or my involvement?

If you require any further information, or have any queries you wish to be answered please do not hesitate to contact Lachlan Mitchell (0431-363-027 or lmit5195@uni.sydney.edu.au)

(10) What if I have a complaint or any concerns?

Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics Administration, University of Sydney, on +61 2 8627 8176 (telephone); +61 2 8627 8177 (facsimile) or ro.humanethics@sydney.edu.au (email).

This information sheet is for you to keep

Version 3

Date: 4/3/2015

C3. Participant consent form for the qualitative study

THE UNIVERSITY OF SYDNEY

Discipline of Exercise and Sport Science
Exercise, Health and Performance Research Group
Faculty of Health Science

ABN 15 211 513 464

Dr Helen O'Connor

SENIOR LECTURER, DISCIPLINE OF EXERCISE & SPORT SCIENCE

Room H106

C42 Cumberland Campus

The University of Sydney

75 East St Lidcombe

NSW 2141 AUSTRALIA

Telephone: +61 2 9351 9625

Facsimile: +61 2 9351 9204

Email: helen.oconnor@sydney.edu.au

Web: http://sydney.edu.au/health-sciences/

PARTICIPANT CONSENT FORM

I, ...[PRINT NAME], give consent to my participation in the research project

TITLE:

THE MODERN BODYBUILDER: NUTRITION AND TRAINING STRATEGIES

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved have been explained to me and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that being in this study is completely voluntary – I am not under any obligation to consent.

4. I understand that my involvement is strictly confidential. I understand that any research data gathered from the results of the study may be published however no information about me will be used in any way that is identifiable.

5. *I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher(s) or the University of Sydney now or in the future.*

6. *I understand that information I provide during the study may be used in future research studies.*

....

Signature

....

Please PRINT name

....

Date

Version 1

Date: 10/11/2014

C4. Interview script for the qualitative study

Interview script

Hello, my name is (insert investigator name) from the University of Sydney. We are conducting a study on nutrition in bodybuilders. As discussed with you, and as you have provided your informed consent, we are now conducting this interview on the dietary strategies used by bodybuilders. Your responses will be confidential to the research team.

I need to go through a few housekeeping items before we start.

- I just want to remind you that the interview is being recorded. Other members of the research team may also listen to the recordings at a later date.
- You may decline to answer any question or section of questions, and can finish the interview at any time.

This work being undertaken by the University of Sydney and is titled the 'The Modern Body Builder: Nutrition and Training Strategies". The overall aim of the study is to develop an understanding of dietary preparation of competitive, natural bodybuilders.

- Mention date and time.

Interview Guiding Questions

I would like to ask you about your diet preparation strategies for each phase of your preparation for competition e.g. 12 months out, 6 weeks out, 1 week out and then the day of and immediately post competition.

Demographic Information & Body Building Experience

Could you please tell me your age and state your gender

What initially attracted you to the sport of body building?

How long have you been body building for now?

Could you tell me about your history in competing?
  when did you start competing
  how many competitions have you entered over that time
  how successful have you been (e.g. any place awards)?
  what category of body building do you compete in now?
  how much longer do you intend to compete for?

Tell me about your training…..
  How often would you say you train in a given week?
  How many hours a week would you train?
  How much of that is weight training and how much is cardio training?

Other bodybuilders

I'm sure there is a lot of "comparing notes" amongst bodybuilders.
  How do you think other bodybuilders train that might be different to what you do?

Diet Intake Questions

Can you tell be about your diet during each of the phases of your training?"
  Why do you follow this specific diet during "x" phase?

  Are there any kinds of foods or food groups you avoid in the different phases?

  Do you have a specific percentage fat/protein/carbohydrate you aim for when creating your meal plans?

Tell me about how strict you are with your diet over the different phases. (Do you have any 'cheat meals' you allow yourself, how regular are these?)

What do you do when you feel hungry/crave or long for certain foods that you are trying to avoid?

What have you tried before that definitely works/definitely doesn't work?

How much time do you spend preparing your food for the day/week?

How do you change your fluid intake during these phases?

How do you keep track of your fluid intake or hydration during these phases?
(possible prompts: Food diaries, dietary intake applications, weighing food)

What does your food/fluid intake look like on the day of competition?

How do you monitor your diet regime is working for you?
(possible prompts: weighing, physique monitoring, skinfolds - they do themselves or have someone not qualified to do, measurements/girths etc)

Other bodybuilders

Do you think there is one type of diet that works for everyone?

What do you think other bodybuilders do differently to you in approach to dietary preparation?

Social aspects

How does your diet impact on your social life/family life?

What role does your partner/family play in support of your dietary changes?

Diet Supplement Questions

What sort of dietary supplements do you use when you are training or preparing for a competition?

(for each mentioned, ask the quantity they use, the frequency and why they use it).

If the participant has indicated that they take supplements: Before I ask you these next questions, I just want to remind you that your answers are confidential and you don't have to answer this one. Do you check the compliance of these supplements with Australian Sports Anti-Doping Agency (ASADA) prohibited lists?

Have you ever taken a supplement on the ASADA prohibited list?

Tell me about any experiences you have had with drug testing as part of your body building competition participation.

<u>Other bodybuilders</u>

What do you think other bodybuilders do with dietary supplements?

Learning about nutrition for bodybuilders

Now I just want to ask you some questions about how you learn about nutrition. To start with, tell me how do you go about learning about nutrition for body building?

Which of these do you find most useful?

How much time a week would you spend in finding out nutrition information?
What area of nutrition knowledge do you feel is most lacking in ………?

<u>Other bodybuilders</u>

From what you have seen and experienced from being around other bodybuilders, how do they learn about nutrition?

C5. Advertisement flyer for the cross-sectional study

THE UNIVERSITY OF SYDNEY

ABN 15 211 513 464

Discipline of Exercise and Sport Science
Exercise, Health and Performance Research Group
Faculty of Health Science

Dr Helen O'Connor
SENIOR LECTURER, DISCIPLINE OF EXERCISE & SPORT SCIENCE

Room H106
C42 Cumberland Campus
The University of Sydney
75 East St Lidcombe
NSW 2141 AUSTRALIA
Telephone: +61 2 9351 9625
Facsimile: +61 2 9351 9204
Email: helen.oconnor@sydney.edu.au
Web: http://sydney.edu.au/health-sciences/

Bodybuilding Research Study

Are you a natural bodybuilder with 5 years' experience training and competing at a National level?

If **YES**, we are looking for male and female bodybuilders to be involved in a research study for the purpose of investigating the nutrition, supplement and training strategies of modern day natural bodybuilders.

The research study involves taking part in a 60 minute interview with questions relating to your nutrition, supplement and training strategies. Participant identity will remain confidential at all times.

Testing for this research study will take place **over the phone, or in person,** at University of Sydney, Cumberland campus, 75 East Street, Lidcombe, or University of Sydney, Camperdown campus, Parramatta Road, Camperdown.

The interviews will be conducted by Accredited Practising Dietitians and Accredited Sports Dietitians who will be available to answer any questions you may have about nutrition and supplements at the completion of the interview

So if you would like to express interest in participating in this study or would like more information please contact

Lachlan Mitchell on 0431 363 027 or email lmit5195@uni.sydney.edu.au,

or Dr Helen O'Connor on 02 9351 9625 or email: helen.oconnor@sydney.edu

Version 3

Date: 4/3/2015

C6. Consent form to advertise study for recruitment purposes

THE UNIVERSITY OF SYDNEY

ABN 15 211 513 464

Discipline of Exercise and Sport Science
Exercise, Health and Performance Research Group
Faculty of Health Science

Dr Helen O'Connor
SENIOR LECTURER, DISCIPLINE OF EXERCISE & SPORT SCIENCE

Room H106
C42 Cumberland Campus
The University of Sydney
75 East St Lidcombe
NSW 2141 AUSTRALIA
Telephone: +61 2 9351 9625
Facsimile: +61 2 9351 9204
Email: helen.oconnor@sydney.edu.au
Web: http://sydney.edu.au/health-sciences/

[*RE: Permission Letter for advertising*]

[*date*]

[*Name and address of health club/gym/supplement store/website for requesting of advertisement*]

Dear [manager/president/etc],

We are in the process of recruiting participants for an exciting study titled 'The modern bodybuilder: Nutrition and Training Strategies.' The overall aim of the study is to identify and describe the nutrition, supplements, and training strategies of bodybuilders in preparation for competition. We are recruiting bodybuilders who are willing to participate in a 60-90 minute interview.

We are therefore seeking your permission for the placement and distribution of the attached advertisement on the website, Facebook page of the [bodybuilding association] to help with the recruitment for this study and would greatly appreciate your cooperation with this study.

Please do not hesitate to contact Mr Lachlan Mitchell on 0431-363-027 (lmit5195@uni.sydney.edu.au) should you have any further inquires.

Kind regards,

[*signature*]

Helen O’Connor

Version 1

Date: 10/11/2014

APPENDIX D: SUPPLEMENTARY MATERIAL FOR CHAPTERS 6 AND 7

D1. Study protocol for the longitudinal study

D2. Participant information sheet for the longitudinal study

D3. Participant consent form for the longitudinal study

D4. Advertisement flyer for the longitudinal study

D5. Consent form to advertise study for recruitment purposes

D1. Study protocol for the longitudinal study

Physiological Implications of Preparing for a Natural Male Bodybuilding Competition

Method

A. Study Design

The Modern Bodybuilder is a longitudinal study investigating changes in physiology, psychology and body composition in adult males during the preparation and recovery from a "natural" bodybuilding competition.

Data collection occurs on five different occasions, over the course of 20 weeks. Participants are invited to attend the University of Sydney Cumberland Campus on each of the five testing points for measurements, as well as being asked to perform further assessments off campus in their own time over the following 7 days. Assessment on campus is expected to take 2-2.5 hours. After the 7 day assessments, participants are to return to the campus with study utensils to receive feedback on assessment results.

The study timeline is centred around each participants' bodybuilding contest. Three testing occasions occur during the 16 weeks prior to the bodybuilding contest. The remaining two testing occasions occur in the four weeks following the contest.

B. Participants

Participants will be recruited using the following methods:

- Flyers in local gymnasiums
- Flyers in local supplement stores
- Flyers posted on the ANB official Facebook page, and subsequently "shared" by Facebook users
- Flyer emailed to participants of previous study, "The Modern Bodybuilder: Nutrition and Training Strategies"
- Word of mouth advertisement
- A stall will be set up at the ANB Nationals contest in October 2015 by the researchers to distribute flyers to competitors, spectators and coaches

Inclusion Criteria:

- Male, aged 20 years and over
- Natural (drug free) bodybuilders, competing in the bodybuilding class at a contest of either the Australasian Natural Bodybuilding or the International Natural Bodybuilding Association.

Exclusion Criteria

- Not competing at a non-natural contest
- Under 20 years of age
- Competing in fitness model or swimwear class
- Performance enhancing drug use

C. Study Parameters

Each collection includes measures of urine specific gravity, bioelectrical impedance, resting metabolic rate, dual-energy x-ray absorptiometry, surface anthropometry, and blood collection, all of which are performed at the University of Sydney Cumberland Campus. In addition to these measures, the following assessments are completed by the participant in the 7 days following these measures: 7-day food diary, 7-day training diary, energy expenditure via SenseWear armbands, MDDI, BIG-O and EAT-26 online questionnaires, and collection of a stool sample.

Participants are to present to campus in the morning after a 12 hour fast from food, fluid and exercise.

On Site Assessments

1. Urine Specific Gravity

Urine Specific Gravity will be measured upon presentation to the campus using the Atago UG-α refractometer. The participant will be asked to provide a small sample of urine in a container. The refractometer is calibrated by the researcher using distilled water, before a drop of the urine provided by the participant is pipetted onto the prism top for analysis. Analysis is performed twice, with the mean urine specific gravity recorded.

2. Body Composition

2.1 Bioelectrical Impedance Analysis

Body composition, total body water and intracellular and extracellular fluid will be measured using bioelectrical impedance analysis using the tetra-polar surface electrode technique. Participants' weight and stretch stature will be measured and input into the Impedimed machine. Participants will be asked to lie flat on a bed in preparation for the bioelectrical impedance analysis. This will be performed by the researcher using an Impedimed SFB7 with dual tab electrodes. Electrode site preparation consists of shaving any hair, and cleaning the site with a 70% ethanol swab. Electrodes are placed on the right side of the body. The proximal hand electrode is placed on the midline of the ulnar styloid process, on the wrist, with the green line of the electrode running along this midline. The distal electrode is subsequently placed toward the fingers. The proximal foot electrode is placed between the medial and lateral malleolus bones, on the ankle, with the green line of the electrode running between the malleoli. The distal electrode is subsequently placed toward the toes. After lying still for 10 minutes, cords running from the Impedimed BSF7 are attached to the electrodes using alligator clips. The yellow sense lead attaches to the proximal hand electrode; the red current source lead attaches to the distal hand lead; the blue sense lead attaches to the proximal foot lead; the black current sink lead attaches to the distal foot lead. Three measures are taken. Results for each three measurements are averaged for participant result.

2.2 Dual Energy X-Ray Absorptiometry

Body composition will also be assessed using dual energy x-ray absorptiometry (DXA). Participants will be scanned using the Lunar Prodigy (GE Lunar Corp, Madison, WI) using a total body scan. The participant is asked to strip to briefs or sports shorts, and remove all jewellery, watches etc. Height and weight are collected, to the nearest 0.1kg, and 0.1cm, respectively. The participant is to lie flat on the table. The technician uses the centreline on the table as a reference to align the participant. The participant is to lie as still as possible for the duration of the scan, taking approximately seven minutes. Tissue %fat, total mass, fat mass and lean mass are documented. The radiation dose participants will be exposed to does not exceed 0.02 mSv and side effects are negligible. DXA measurements will be performed by a trained technician.

2.3 Surface Anthropometry

Surface anthropometry will be used as another measure of body composition. An accredited anthropometrist will mark and measure the participant using a Harpenden skinfold caliper, Lufkin Executive steel tape measure, sliding caliper, and segmometer. Eight skinfold sites will be measured, (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf); 12 girths will be measured (head, neck, arm relaxed, arm flexed and tensed, forearm, wrist, chest, waist, hips, thigh 1 cm below gluteal fold, thigh mid trochanter-tibiale, calf, ankle); 10 lengths will be measured (acromiale-radiale, radiale-stylion, midstylion-dactylion, trochanter-tibiale laterale, tibiale med-sphyrion tib, foot length, sitting height, iliospinale-box height, troch-box height, tibiale laterale-box height); 6 breadths will be measured (biacromial, biiliocristale, transverse chest, AP chest depth, humerus, femur). All measures will be taken in duplicate.

3. Physiological Parameters

3.1 Resting Metabolic Rate

Resting metabolic rate will be measured via indirect calorimetry using the COSMED Quark CPET metabolic cart. The cart will be calibrated prior to gas collection according to manufacturer instructions. Along with the 12 hour food and fluid fast, participants are asked to abstain from exercise for 12 hours before testing, and to limit physical activity the morning of the test. This includes walking, stair climbing, and house work. Testing will take place in a small, quiet room, away from noisy machinery, with a comfortable room temperature. After completion of BIA measurement, participants are fitted with a face mask and continue lying on a bed in a comfortable position, for 30 minutes of gas collection. The final 15 minutes of sampling is saved and used for analysis. VO_2, VCO_2, and energy expenditure are documented and averaged. RMR is determined from this data. Room lights are dimmed for testing, and participants are asked to remain still, to breathe normally and to remain awake.

3.2 Venepuncture

Blood will be collected by a trained venipuncturist. A total of 9 tubes will be collected, equating to approximately 43 mL of whole blood. Blood will be collected from the antecubital vein with the following criteria: 12 hour fast from food, no exercise or alcohol for 12 hours, and showing no signs of infection or illness at the time of blood draw.

Blood parameters to be measured:

- Leptin
- Ghrelin
- Adiponectin
- Testosterone
- Insulin
- Electrolytes (sodium, potassium, calcium, magnesium)
- Albumin
- eGFR
- Glucose
- Cholesterol, HDL, LDL, triglycerides
- β-hydroxy butyrate
- Serum Osmolality

Blood will be collected into two precooled on ice 2 mL potassium oxalate/sodium fluoride tubes, one precooled on ice 9 mL EDTA tube, and six 5mL SST tubes. The EDTA and potassium oxalate/sodium fluoride tubes will immediately be plunged back into the ice water. Tubes will be centrifuged at 2000 x g for 15 minutes at 4˚C, before plasma/serum is pipetted in 0.5mL volumes into cryovial Eppendorf tubes and frozen at -80˚C. Blood processing will take place in the L204 laboratory, and serum/plasma storage will be in freezers in the H108 laboratory.

Off Site Assessments

The following measures are completed off campus by the participant in the 7 days following the above measures.

4. Seven Day Food Diary

The participant will complete a seven day food diary, documenting all food, fluid, and supplements consumed. Serving size (weighed if possible), meal preparation method and meal timing is to be documented.

5. Seven Day Training Diary

The participant will complete a seven day training diary, documenting all exercise completed. The participant will document the number of repetitions, the weight lifted, the effort required, the speed of the movement, and the rest between every set of every resistance exercise. Details for each variable are as follows:

Repetitions: the number of repetitions in a set
Weight lifted: The weight used for the set. This is presented in kg, lbs, body weight, or machine weight
Effort: This will be presented using a scale of 1-10, where 1 is very easy, and 10 is maximal effort.

Speed: This is presented using four numbers, each representing a phase of the movement. The phases are eccentric, a pause at the end of eccentric, concentric, and a pause at the end of concentric. Results should appear as E.P.C.P e.g. 2.0.1.1
Rest: This is the recovery time, in minutes or seconds, between sets of the exercise.

Aerobic/Cardio/Anaerobic exercise will be documented in a similar fashion. The mode, structure, duration, intensity, and details of all aerobic/ cardio/anaerobic exercise will be documented. Details for each variable are as follows:

Mode/type: For example running, cycling, swimming
Structure: For example interval training, steady state exercise
Duration: The duration of session in minutes or hours is documented
Intensity: The intensity of the exercise can be provided in many different units, such as %HRmax, HR, RPE/effort (1-10 scale)
Details: The detail of the session is to include as much information as possible. This would include any information not documented in previous variables, such as interval duration, distance, recovery time, power output.

6. SenseWear armbands

The SenseWear armband is a small band fitted around the upper arm used for calculating total energy expenditure, active energy expenditure, resting energy expenditure, total number of steps, physical activity duration, sleep duration, and lying down duration, based on measurement of skin temperature, galvanic skin response, heat flux, and a 2-axis accelerometer. The participant is to wear the band for three complete days of the seven day period. These days do not need to be consecutive. These three days should consist of two training days and one non-training day. If there are no non-training days in the participants schedule then the band should be worn for three training days. The band is to be worn at all times, except during water activities (e.g. swimming, showering). This includes training sessions. One day is constituted by an entire 24 hour period, e.g. 9am to 9am. The band is placed on the right upper arm, so that the two sensors are in direct contact with the skin over the triceps muscle. Skin should be clean and dry, with no moisturiser or oil present. The sensor begins data collection within 10 minutes of placement, and is indicated by a progression of tones.

7. Online psychology questionnaires

7.1 Muscle Dysmorphic Disorder Inventory

The Muscle Dysmorphic Disorder Inventory (MDDI) is a brief, 13 item questionnaire. The MDDI uses a 5 point Likert-type scale for responses, ranging from “never” to “always”. The questions are preceded by the statement, “Please respond to each of the following statements. For each question, select the option that most closely describes how the statement applies to you right now.” This questionnaire is completed by the participant online, on a training day. A link to the questionnaire is sent to the participants email address. The questionnaire is hosted by the server www.qualtrics.com. The participant is to respond to all questions before submitting.

7.2 Bodybuilder Image Grid-Original

The Bodybuilder Image Grid-Original (BIG-O) is a 4 item questionnaire, which requires the participant to respond to questions based on a grid of 30 body silhouettes. The questions and grid are preceded by the statement, "For each of the following four questions, you will be asked to choose which of these figures the male body asked about best represents. You will indicate for each question the numerical value (from 1-30) that corresponds to the figure as requested." This questionnaire is completed by the participant online, on a training day. A link to the questionnaire is sent to the participants email address. The questionnaire is hosted by the server www.qualtrics.com. The participant is to respond to all questions before submitting.

7.3 Eating Attitude Test-26

The Eating Attitude Test-26 (EAT-26) is a 26 item questionnaire. The EAT-26 uses a 6-point Likert-type scale for responses, ranging from "never" to "always". The questions are preceded by the statement, "Please respond to each of the following statements. For each question, select the option that most closely describes how the statement applies to you right now." This questionnaire is completed by the participant online, on a training day. A link to the questionnaire is sent to the participants email address. The questionnaire is hosted by the server www.qualtrics.com. The participant is to respond to all questions before submitting.

8. Stool Sample

At each measurement point, participants will be provided with a stool collection kit, containing a pair of latex gloves, a labelled sterile collection container with spoon on the inside of the lid, a zip lock bag, and collection instructions. The faecal sample will be used to measure gut microbiota colonies. Participants are instructed to pass a stool into a clean milk carton or onto a newspaper, being sure to avoid any water or urine contacting the stool. After washing hands and wearing the latex gloves, they will use the spoon on the inside of the container lid to scoop a small portion, about the size of a ping pong ball, into the container and screw on the lid. Once closed they will document the time and date of sample collection on the container label, then lock inside the zip lock bag. The sample will immediately be placed into the participant's freezer. The sample will be returned to the university campus at the completion of the seven day data collection period, and placed inside the -80˚C freezer. Participants are advised to leave the sample in their personal freezer until just prior to travelling to the campus, to avoid the sample thawing out.

At the conclusion of the seven day data collection period, each participant will return to campus with their completed 7-day food diary, 7-day training diary, SenseWear band, and frozen stool sample. At this point results from the on-campus measures can be provided to the participant, minus the blood test results.

43 mL of blood drawn into 9 tubes labelled with participant ID, time and date of collection

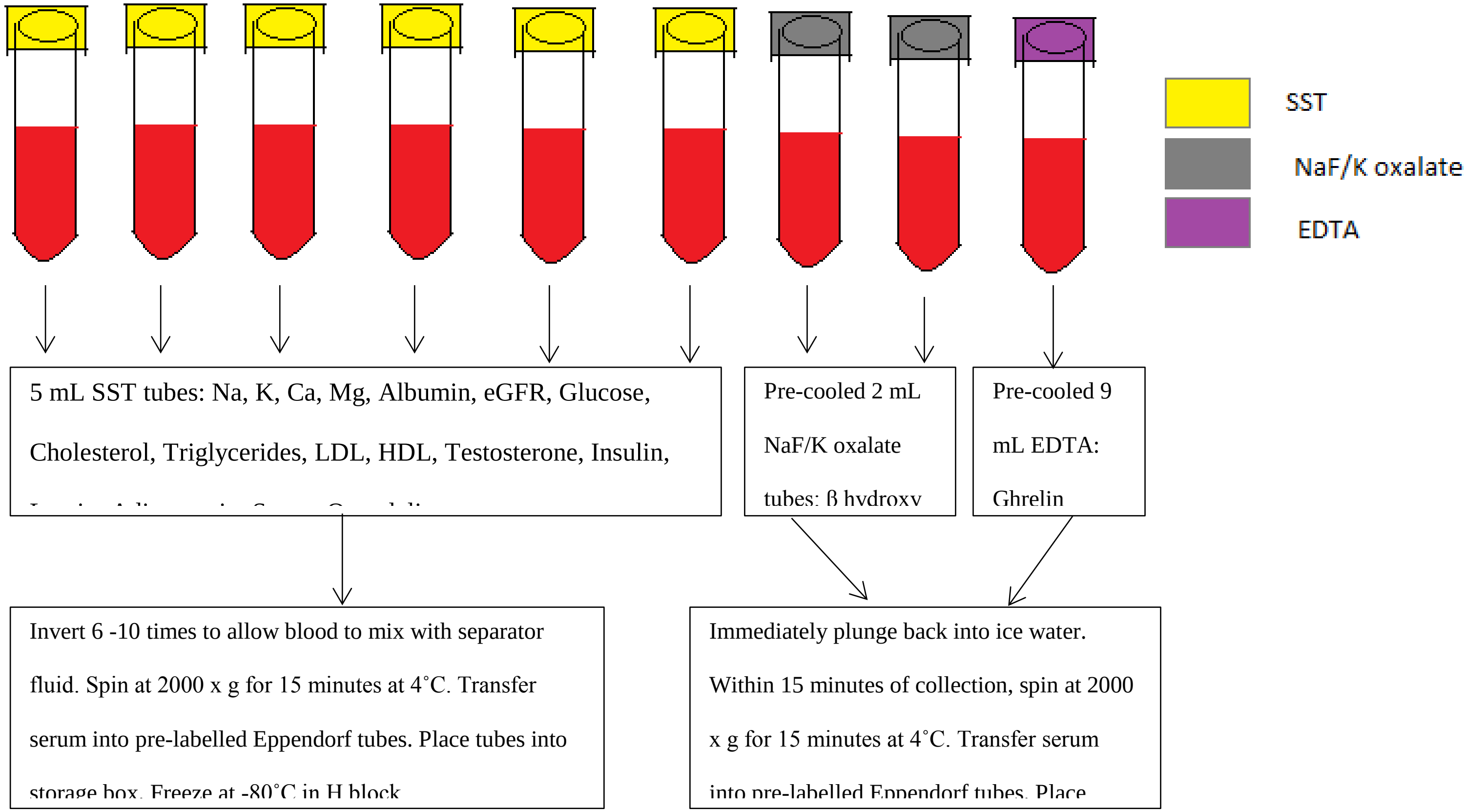

Figure D1. Blood Draw and Processing Chart

Labelling and storage of bloods

Labelling of Eppendorf's for freezer storage

Using a fine tip permanent marker label each Eppendorf with participant code, date, and type of collection tube e.g. SST, EDTA, NaF/K oxalate

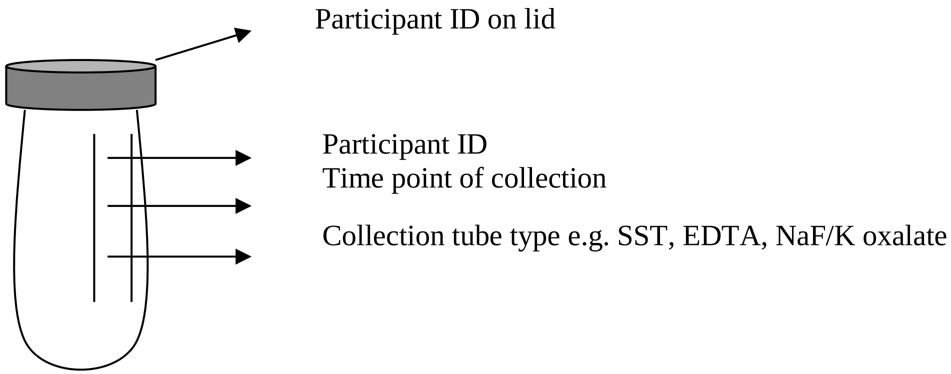

Figure D2. Eppendorf labelling

After centrifuging, pipette approximately 0.5mL of plasma/serum into the appropriate Eppendorf tubes. Transport tubes in labelled freezer boxes, then store in -80˚C freezer located in H block laboratory.

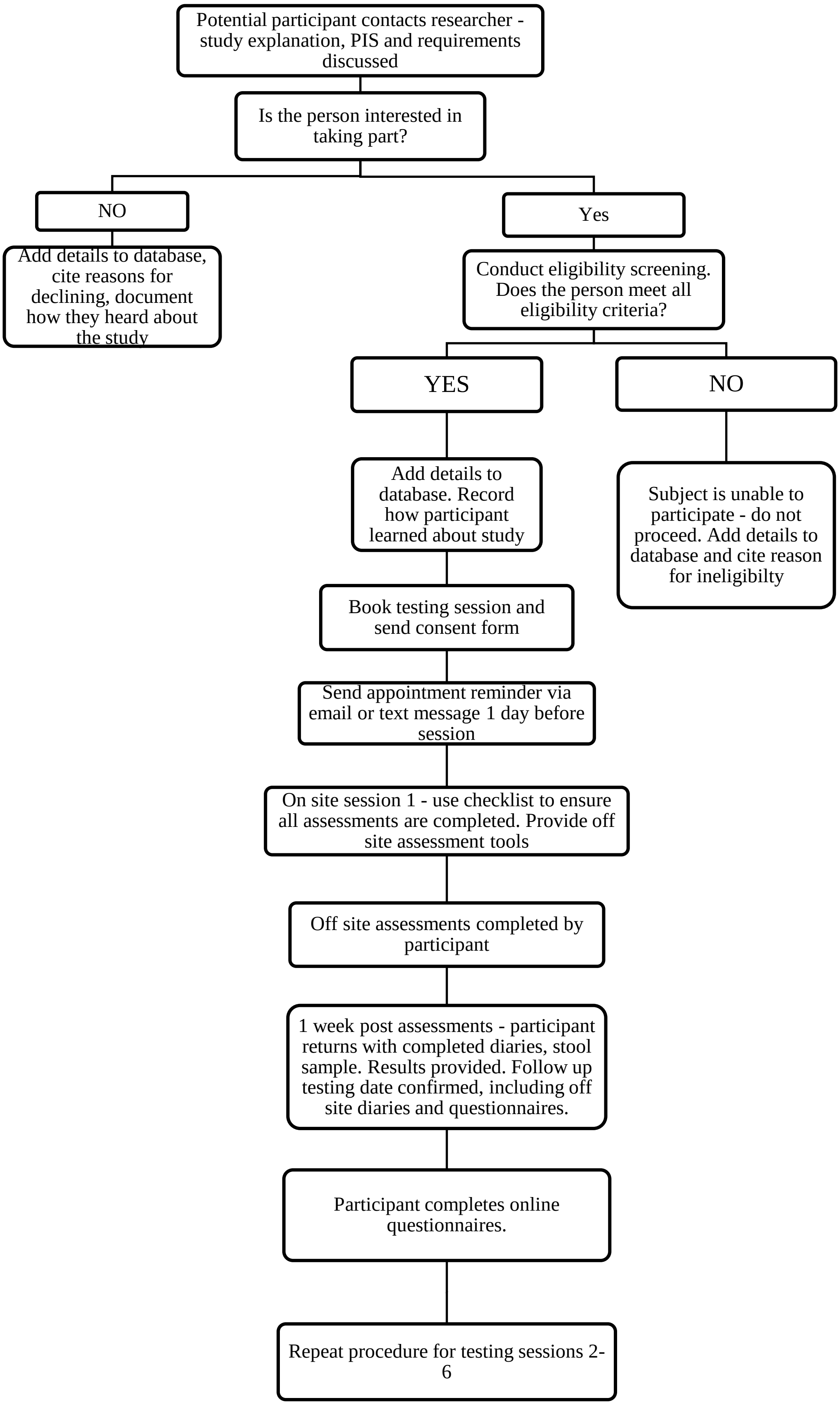

Figure D3. Flowchart of recruitment and study methods

Timeline of Events

1. Timetable

Table D1. Schedule of recruitment and assessment

Parameter	Pre		-16		-12	-8		-4	-1		1		4	
	On site	Off site	On site	Off site	Off site	On site	Off site	Off Site	On site	Off site	On site	Off site	On site	Off site
Recruitment														
Screening		X												
Information pack		X												
Consent														
Study consent														
Hydration														
USG			X			X			X		X		X	
Body composition														
BIA			X			X			X		X		X	
DXA			X			X			X		X		X	
Anthropometry			X			X			X		X		X	
Physiology														
RMR			X			X			X		X		X	
Biomarkers														
Blood collection			X			X			X		X		X	
Stool collection				X			X			X		X		X
Diaries														
Food diary				X			X			X		X		X
Training diary				X			X			X		X		X
Questionnaires														
MDDI				X	X		X	X		X		X		X
BIG-O				X	X		X	X		X		X		X
EAT-26				X	X		X	X		X		X		X
Energy Expenditure														
SenseWear				X			X			X		X		X

2. Breakdown of Testing Sessions

1. Pre-testing

1.1 Provide Information to potential participants via phone or email. Document all enquiries in the recruitment tracking sheet.
1.2 Screen participant, document outcomes in participant tracking sheet.
1.3 If eligible, book in testing session.
1.4 Send participant information statement to participant via email or post. Ask participant to read carefully and to ask any questions when they arrive for the first session.
1.5 Instruct the participant to present to the campus on the morning of their session fasted for 12 hours from food and fluid, and to avoid exercise for 12 hours before the session. To obtain an accurate RMR measure, also advise them to be as inactive as possible the morning of the session.

2. On Site (2.5 Hours)
2.1 Assign participant identification number.
2.2 Explain the structure and function of the study. Complete participant consent form.
2.3 Complete bodybuilding background information form.
2.4 Ask participant to void their bladder, and provide a urine sample. Complete USG test.
2.5 Measure weight and stretch stature.
2.6 Lie participant on bed for 10 minutes, and prepare them for BIA measurement. While lying down, complete bodybuilding background form. After 10 minute lying, and placement of electrodes, take three consecutive BIA measures.
2.7 With participant still on bed, fit the gas mask onto participant for RMR test. Instruct participant to remain very still, and to breathe normally, then begin 30 minute expired gas analysis. The room should be quiet, dimly lit, and at a comfortable temperature. The participant should limit movement during the collection period, so advise them to find a comfortable position to lie in before collection begins. It is important the participant does not fall asleep, therefore if this begins to occur, gently nudge the participant.
2.8 Upon completion of RMR, remove mask from participant, and escort them to the DXA machine. Ask participant to strip to briefs or light shorts for the DXA scan. Set the participant up on the DXA table then begin the scan.
2.9 Escort participant back to H block testing room. Ask participant to strip to briefs or light shorts to begin surface anthropometry. Palpate and mark the complete profile, then take the 8 skinfolds, 12 girths, 10 lengths, and 6 breadths, in duplicate. Duplicate skinfolds with greater than 5% error are measured a third time, and duplicate girths, lengths and breadths greater than 1% error are measured a third time.
2.10 Explain to participant the procedures for completing the food and training diaries, the SenseWear arm band, the online questionnaires, and stool sample collection. Provide them with the stool collection kit.
2.11 Prepare participant for blood collection. Have 9 tubes ready, with the 2 sodium fluoride/potassium oxalate tubes and the EDTA tube precooled in ice water. Once each tube has been filled, immediately place NaF and EDTA tubes back in ice water.
2.12 Use assessment checklist to ensure all measures have been taken.

2.13 Thank participant and book in the return visit for one week later, when off-site measures will be returned, and result feedback given.
2.14 Process bloods.
2.15 Data entry.
2.16 Email the links to the online questionnaires to the participant.

3. Off Site

3.1 Participant is to complete the seven day food diary, documenting all food, fluid and supplements consumed, the time they are consumed, and the preparation method used. If they have the capacity to weigh their food this should be attempted.
3.2 Participant is to complete the seven day training diary, documenting all details of each training session they complete.
3.3 Participant is to wear the SenseWear arm band for three complete days. The sensors should be in direct contact with the skin over the triceps muscle on the right upper arm. The days worn should be documented in the food diary.
3.4 The participant will receive a link to each of the online questionnaires via email. To standardise the test conditions, these should all be completed in one sitting, on a training day. Once each question has been answered, the participant can submit their completed questionnaire.
3.5 The participant will use the stool collection kit to collect a small sample of faeces passed. With the provided latex gloves on, and after placing a clean milk carton or newspaper in the toilet bowl, the participant is to pass a bowel movement, avoiding contact of water or urine on the sample. Scoop a small amount (ping pong ball size) into the container using the spoon on the underside of the container lid. Close the container, label with date and time, lock in zip lock bag, and immediately place in home freezer.

4. Returning to campus

4.1 Seven days after the on campus tests, the participant is to return to campus with the completed food diary, training diary, SenseWear band and frozen stool sample.
4.2 The stool sample should be left in the home freezer until travelling to the campus. Once the participant has arrived, the researcher should immediately place the sample in the -80˚C freezer.
4.3 Researcher is to visually check the food and training diaries for completeness.
4.4 Connect SenseWear to computer and load data to confirm three complete days of data have been collected. If not, ask participant to wear for the required days and return when done.
4.5 Provide participant with results of RMR, skinfolds, BIA assessments.
4.6 Thank participant for returning
4.7 Organise next visit for repeat testing.
4.8 Online questionnaires will be completed midway between current testing point and next complete testing point – organise a reminder for this, and provide participant with online link.

5. Follow Up On Site Sessions (90 minutes)

5.1 Ask participant to void their bladder, and provide a urine sample. Complete USG test.
5.2 Lie participant on bed for 10 minutes, and prepare them for BIA measurement. After 10 minute rest, and placement of electrodes, take three consecutive BIA measures.

5.3 With participant still on bed, fit the gas mask onto participant for RMR test. Instruct participant to remain very still, and to breathe normally, then begin 30 minute expired gas analysis. The room should be quiet, dimly lit, and at a comfortable temperature. The participant should limit movement during the collection period, so advise them to find a comfortable position to lie in before collection begins. It is important the participant does not fall asleep, therefore if this begins to occur, gently nudge the participant.
5.4 Upon completion of RMR, remove mask from participant, and escort them to the DXA machine. Ask the participant to strip to briefs or light shorts for the DXA scan. Set the participant up on the DXA table then begin the scan.
5.5 Escort the participant back to the H block testing room. Ask participant to strip to briefs or light shorts to begin surface anthropometry. Palpate and mark the complete profile, then take the 8 skinfolds and 12 girths, in duplicate. Duplicate skinfolds with greater than 5% error measure a third time, and duplicate girths greater than 1% error measure a third time. (Lengths and breadths will not change between sessions therefore only measured on initial testing session).
5.6 Provide a repeat explanation to participant of the procedures for completing the food and training diaries, the SenseWear arm band, and stool sample collection. Provide them with the stool collection kit.
5.7 Prepare participant for blood collection. Have 9 tubes ready, with the 2 sodium fluoride/potassium oxalate tubes and the EDTA tube precooled in ice water. Once each tube has been filled, immediately place NaF and EDTA tubes back in ice water.
5.8 Use assessment checklist to ensure all measures have been taken.
5.9 Thank participant and book in the return visit for one week later, when off-site measures will be returned, and result feedback given.
5.10 Process bloods.
5.11 Data entry.
5.12 Email the links to the online questionnaires to the participant.

6. Off Site

6.1 Participant is to complete the seven day food diary, documenting all food, fluid and supplements consumed, the time they are consumed, and the preparation method used. If they have the capacity to weigh their food this should be attempted.
6.2 Participant is to complete the seven day training diary, documenting all details of each training session they complete.
6.3 Participant is to wear the SenseWear arm band for three complete days. The sensors should be in direct contact with the skin over the triceps muscle on the right upper arm. The days worn should be documented in the food diary.
6.4 The participant will receive a link to each of the online questionnaires via email. To standardise the test conditions, these should all be completed in one sitting, on a training day. Once each question has been answered, the participant can submit their completed questionnaire.
6.5 The participant will use the stool collection kit to collect a small sample of faeces passed. With the provided latex gloves on, and after placing a clean milk carton or newspaper in the toilet bowl, the participant is to pass a bowel movement, avoiding contact of water or urine on the sample. Scoop a small amount (ping pong ball size) into the container using the spoon on the underside of the container lid. Close the container, label with date and time, lock in zip lock bag, and immediately place in home freezer.

7. Returning to campus
7.1 Seven days after the on campus tests, the participant is to return to campus with the completed food diary, training diary, SenseWear band and frozen stool sample.
7.2 The stool sample should be left in the home freezer until travelling to the campus. Once the participant has arrived, the researcher should immediately place the sample in the -80˚C freezer.
7.3 Researcher is to visually check the food and training diaries for completeness.
7.4 Connect SenseWear to computer and load data to confirm three complete days of data have been collected. If not, ask participant to wear for the required days and return when done.
7.5 Provide participant with results of RMR, skinfolds, BIA assessments.
7.6 Thank participant for returning
7.7 Organise next visit for repeat testing. Online questionnaires will be completed midway between current testing point and next complete testing point – organise a reminder for this, and provide participant with online link.

Scripts

Initial email script

"Hi [Insert name],

Thank you for expressing interest in taking part in our study, The Modern Bodybuilder.
Our study will involve following participants as they prepare for the national bodybuilding titles, taking measurements on 5 occasions over a 20 week time period. The measures will include body composition - skinfolds, DXA scan, BIA; resting metabolic rate; blood tests including appetite hormones; diet analysis, energy expenditure, some basic psychological assessments, and gut microbiota. In a nutshell we will be measuring the changes in your metabolism as you prepare and recover from the contest, and how this affects other systems of your body. I have attached an information statement which gives a complete run down of our study.

The measures will be done at the University of Sydney Cumberland Campus, Lidcombe, and will take 1.5-2.5 hours. Testing is done in the morning as we require you to present fasted.

We would love to have you involved. If you would like more information or would like to proceed, the next step is to conduct a brief telephone screen (3 minutes) to check the eligibility criteria is met. If so, let me know the best time and number to contact you on, and I will give you a call. Alternatively please feel free to contact me at your convenience on 0431 363 027.

Kindest regards,

Lachlan Mitchell"

Invitation email to participants of The Modern Bodybuilder: Nutrition and training strategies

"Dear [participant name],

Continuing on from our current research project, we are now in the process of recruiting bodybuilders for a study titled "The Modern Bodybuilder: Physiology, psychology and body composition changes in preparation for a bodybuilding competition. A longitudinal study." Please see the attached advertisement flyer for project information.

If you are interested in taking part in this exciting study, or would like more information, please contact Lachlan Mitchell via email or phone:

lmit5195@uni.sydney.edu.au

0431363027

Kindest regards"

Collection Forms

Pre assessment

- Participant consent form
- Consent to advertise study in gymnasium, supplement store, Facebook page

On site assessment

- Bodybuilder history form
- BIA assessment form
- DXA results form (print off from DXA computer)
- Surface anthropometry form
- Assessment checklist

Off site assessment

- Food diary
- Training diary

Participant handouts

- Stool collection kit, including collection instruction handout
- Take home package: food diary, training diary, SenseWear armband
- SenseWear user guide

D2. Participant information sheet for the longitudinal study

THE UNIVERSITY OF SYDNEY

ABN 15 211 513 464

Discipline of Exercise and Sport Science
Exercise, Health and Performance Research Group
Faculty of Health Science

Dr Helen O'Connor
SENIOR LECTURER, DISCIPLINE OF EXERCISE & SPORT SCIENCE

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Web: http://sydney.edu.au/health-sciences/

The Modern Bodybuilder: Physiology, psychology and body composition changes in preparation for a bodybuilding competition. A longitudinal study.

PARTICIPANT INFORMATION STATEMENT

1. What is the study about?

You are invited to participate in a study called "The Modern Bodybuilder: Physiology, psychology and body composition changes in preparation for a bodybuilding competition." The overall aims are to assess and describe dietary, training, psychology, physiology and body composition changes in competitive, natural bodybuilders, during a period of competition preparation and recovery.

2. Why are we doing this study?

We are conducting this study to learn about the preparation of competitive bodybuilders and the effect of diet, training and competition on their physical and psychological health.

3. Who is carrying out the study?

The study is being conducted at The University of Sydney (Faculty of Health Sciences, Cumberland Campus, 75 East Street Lidcombe NSW 2141) by the following researchers:

Faculty of Health Sciences, University of Sydney

- Dr Helen O'Connor
- Dr Daniel Hackett
- Dr Stephen Cobley

- Dr Janelle Gifford
- Dr Nathan Johnson
- Mr Lachlan Mitchell (PhD Candidate)
- Dr Gary Slater, Faculty of Science, Health, Education and Engineering, University of Sunshine Coast
- Dr Stuart Murray, Department of Psychiatry, University of California San Diego

4. What does the study involve?

The study involves a battery of assessments, which will be performed on 8 different occasions over a 6 month period. If you agree to participate in this study you will be asked to sign the Participant Consent Form, and present to the Cumberland Campus of the University of Sydney (Lidcombe) on 6 occasions to be measured. These measurement sessions will take 1.5-2.5 hours. Further to this you will be required to return to the Cumberland campus 6 more times to return analysis equipment. You will also be asked to complete two further assessment points on the internet, which do not require you to present to the University.

During the study you will undergo the following:

- Dual-energy X-ray Absorptiometry (DXA) scans
- Bioelectrical Impedance Analysis (BIA)
- Resting Metabolic Rate analysis
- Surface anthropometry (skinfolds and girth measurements)
- Blood tests
- Food diary
- Energy expenditure assessments
- Training record
- Eating pathology and body image assessments
- Gut bacteria analysis (stool sample collection)

All assessments are described in detail below.

Dual-energy X-ray Absorptiometry (DXA)

A DXA scan will be used to determine the amount of muscle, fat and bone in your body. The DXA measure will require that you lay on a table whilst the images will be obtained. Each scan will expose you to a very small dose of ionising radiation. The DXA scan is expected to take between 10 and 15 minutes.

Bioelectrical Impedance Analysis (BIA)

A BIA will be used to measure the amount of water in your body. It will also provide a second measure of the amount of muscle and fat in your body. The BIA will require you to lie on a table while small electrodes are taped to your hand and foot and a small non-detectable electric current will be passed through your body for a second. This test poses no risk or discomfort to you and takes about 5 minutes to perform.

Resting Metabolic Rate (RMR) analysis

After resting on a bed for 30 minutes, you will wear a mask with an attached mouth piece so that we can measure all the air you breathe in and out. This will take 20 minutes, and you will need to lie still. The inspired and expired air you breathe will allow us to calculate you resting metabolic rate.

Surface Anthropometry

Surface anthropometry will be assessed by measuring 8 skinfolds, 13 girths, 9 lengths and 8 breadths, located on the right side of the body. A trained and certified anthropometrist will locate the anatomical landmarks and also take the measurements. Additionally, standing height and weight will be recorded. Measurements will be carried out while standing with your elbows and knees extended and relaxed, but you can sit down in-between measurements. Complete surface anthropometry assessment is expected to take between 45-60 minutes on the first assessment. Subsequent surface anthropometry assessments are expected to take 30-45 minutes.

Blood tests

Blood sampling will be performed to measure appetite hormones, body salts (electrolytes), blood proteins and hormones (including testosterone), blood glucose, insulin, blood lipids (fats) and body hydration (osmolarity) while you are fasted. Venous blood will be drawn by a certified venepuncturist from a site on the arm. There may be slight discomfort associated with collecting the blood sample, and a small risk of bruising at the site.

Food Diary

You will be required to keep a one week food diary (either using a booklet provided or a phone application: Easy Diet Diary), recording all food, fluid and supplements consumed over a seven day period on each of the 8 occasions of measurement. The seven days will be consecutive. At the conclusion of the seven day recording you will be required to return the written diary to the University, along with your Sense Wear armband, seven day training record and stool sample (see below)

Energy Expenditure

You will be asked to wear a Sense Wear armband on your upper left arm over three days. The three days will be consecutive and cover two training days and one non-training day. These three days will be the first three days of the food diary collection. You will be provided with this arm band, and you will be required to return this arm band to the University each time you complete this measurement.

Training record

You will be asked to complete a training record during the same seven day period as the food diary analysis. The training record requires you to document all planned exercise performed over the seven days, including the exercises, number of sets, number of repetitions, the resistance used, the rest period, the intensity of exercise, the session duration and the rate of perceived exertion. You will be required to return your written training record with your food diary, Sense Wear arm band and stool sample at the conclusion of each one week collection period.

Eating behaviour and body image assessments

You will be asked to complete three different online questionnaires. Two of these will assess body image, and the third will assess eating behaviours and attitudes.

Gut bacteria analysis

Gut bacteria cultures will be measured through the analysis of a stool sample. In order to do this you will be asked to provide a small faecal sample, by collecting and freezing a sample off site on the final day of your seven day food diary period. You will then be asked to present this to the researchers at the University of Sydney Cumberland campus with your food diary, training record and Sense Wear armband. You will be provided with a small, sterile collection container, sterile collection spoon, and non-latex gloves.

Risks

During the course of taking blood samples, mild pain and/or bruising may occur at the site of the needle entry. The total amount of blood taken over the 6 month study is small and will not result in any harm.

Radiation

This research study involves exposure to a very small amount of radiation from x-rays. The effective dose of radiation from this study is about 0.2 millisieverts (mSv). For comparison, everyone receives a dose of about 2 mSv each year from natural sources as part of everyday living, so the study is equivalent to a few weeks of natural ‘background’ radiation. No harmful effects have been demonstrated at this level and the risk is minimal.

Please inform our researchers if you have participated in any research study in the last five years where you were exposed to radiations. If you volunteer for another research study in the next 5 years, you should take this statement with you and show it to the researchers.

Psychological distress

This research study involves assessment of body image and eating attitudes. As a result of these assessments some psychological distress may be encountered. A clinical psychologist will screen all questionnaire responses and provide lay feedback to participants when necessary. A referral to an independent psychologist will be offered to participants whom are displaying significant signs of psychological distress or a psychological condition.

5. How much time will the study take?

You will need to come to the University of Sydney, Cumberland Campus, on 12 different occasions. Six occasions for measurements and a further six occasions to return assessment tools. The initial visit will involve an introduction and baseline measurements, and is expected to last 2-2.5 hours. All measurements will be taken on this visit. Subsequent visits to the University are expected to last 1.5 hours. DXA, BIA, RMR, surface anthropometry and blood collection will take place at the University on these visits. You will be asked to complete the eating behaviour and body image assessment tools online at these measurement points. In addition you will be required to complete the food diary, training record, Sense Wear and a stool sample collection during the seven days after these subsequent visits.

6. Will I be given a training program and diet to follow?

No. We will not be intervening into your competition preparation or recovery. We will not provide you with any training or nutrition programs to follow. We want you to follow your regular competition diet, supplement and training regimen, as our aim is to measure changes in your body resulting from your dietary and training habits. After the study is finished we will be able to review all of the measures (except for blood and stool which will take longer to analyse) and provide feedback on your diet and training program.

7. Can I withdraw from the study?

During all study procedures, you will be monitored very closely by qualified and experienced health professionals. Being in this study is completely voluntary – you are not under any obligation to give your consent and, if you do not consent, you can withdraw at any time without affecting your relationship with The University of Sydney. You may also be withdrawn from the study by us, if we find that your participation may be unhealthy to you.

8. Will anyone else know the results?

All aspects of the study, including results, blood test findings etc. will be strictly confidential and only the researchers will have access to information on participants, except as required by law. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

The data collected in this study may be used in future research studies by the research group. The data will remain confidential, and only researchers will have access to the information.

9. Will the study benefit me?

Yes. You will receive relevant feedback to your competition preparation regarding your body composition. You will be assessed using highly accurate tools by experienced, qualified health professionals, which otherwise may not be available to you. The researchers will also be available to provide feedback regarding your results. A lay summary will be given to you at the conclusion of the study.

10. Can I tell other people about the study?

Yes, you can! If you know any other male natural bodybuilders competing at the national contests please tell them about this study.

11. What if I require further information about the study or my involvement?

If you require further information about the study, or have any queries you wish to be answered, please do not hesitate to contact Lachlan Mitchell (lmit5195@uni.sydney.edu.au or 0431-363-027).

12. What if I have a complaint or any concerns?

Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics administration, University of Sydney, on +61 2 8627 8176 (telephone); +61 2 8627 8177 (facsimile); or ro.humanethics@sydney.edu.au (email).

This information sheet is for you to keep

Version 2

Date: 10/6/2015

D3. Participant consent form for the longitudinal study

Discipline of Exercise and Sport Science
Exercise, Health and Performance Research Group
Faculty of Health Science

ABN 15 211 513 464

Dr Helen O'Connor
SENIOR LECTURER, DISCIPLINE OF EXERCISE & SPORT SCIENCE

Room H106
C42 Cumberland Campus
The University of Sydney
75 East St Lidcombe
NSW 2141 AUSTRALIA
Telephone: +61 2 9351 9625
Facsimile: +61 2 9351 9204
Email: helen.oconnor@sydney.edu.au
Web: http://sydney.edu.au/health-sciences/

PARTICIPANT CONSENT FORM

I, ...[PRINT NAME], give consent to my participation in the research project

TITLE:
THE MODERN BODYBUILDER: PHYSIOLOGY, PSYCHOLOGY AND BODY COMPOSITION CHANGES IN PREPARATION FOR A BODYBUILDING CONTEST. A LONGITUDINAL STUDY

In giving my consent I acknowledge that:

7. The procedures required for the project and the time involved have been explained to me and any questions I have about the project have been answered to my satisfaction.

8. The procedures will take place both on site at the University of Sydney, Cumberland Campus, and off site.

9. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

10. I understand that being in this study is completely voluntary – I am not under any obligation to consent.

11. I understand that my involvement is strictly confidential. I understand that any research data gathered from the results of the study may be published however no information about me will be used in any way that is identifiable.

12. I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher(s) or the University of Sydney now or in the future.

13. There is a very low risk of skin irritation and bruising at the site where blood is drawn from the arm.

8. I understand I will be exposed to a very low dose of radiation associated with the DXA scan. No harmful effects have been demonstrated at this level and the risk is minimal.

9. Information collected during this study may be used in future research carried out by the research group.

....

Signature

....

Please PRINT name

....

Date

Version 2

Date: 5/6/2015

D4. Advertisement flyer for the longitudinal study

Dr Helen O'Connor
Exercise, Health and Performance Research Group
C42 Cumberland Campus
The University of Sydney
75 East Street Lidcombe, NSW 2141
T: +61 2 9361 9625 **E:** helen.oconnor@sydney.edu.au
W: www.sydney.edu.au/health-sciences/

PARTICIPANTS NEEDED

BODYBUILDING RESEARCH STUDY

Are you a natural bodybuilder competing at the INBA Australian National Championships or the ANB Australian Titles?

<u>If YES you may be eligible to participate in an exciting study</u>

We are seeking natural male bodybuilders aged 20 years and over to take part in a research study measuring nutrition, exercise, body fat, muscle mass, metabolic rate, appetite hormones, body image and gut bacteria during preparation and recovery from a national bodybuilding contest.

Testing will occur on 8 occasions, over a 6 month period, and will take place at University of Sydney, Cumberland Campus, 75 East St Lidcombe.

You will receive accurate feedback about your competition preparation from highly experienced Accredited Practising Dietitians, Accredited Sports Dietitians, and Exercise Physiologists.

So if you would like to express interest in participating in this study, or would like more information, please contact

Mr Lachlan Mitchell on 0431 363 027 or email lachlan.mitchell@sydney.edu.au,

Or Dr Helen O'Connor on 02 9351 9625 or email helen.oconnor@sydney.edu.au

Version 1

Date: 4/5/2015

D5. Consent form to advertise study for recruitment purposes

THE UNIVERSITY OF SYDNEY

ABN 15 211 513 464

Discipline of Exercise and Sport Science
Exercise, Health and Performance Research Group
Faculty of Health Science

Dr Helen O'Connor
SENIOR LECTURER, DISCIPLINE OF EXERCISE & SPORT SCIENCE

Room H106
C42 Cumberland Campus
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NSW 2141 AUSTRALIA
Telephone: +61 2 9351 9625
Facsimile: +61 2 9351 9204
Email: helen.oconnor@sydney.edu.au
Web: http://sydney.edu.au/health-sciences/

[*RE: Permission Letter for advertising*]

[*date*]

[*Name and address of health club/gym/supplement store/website for requesting of advertisement*]

Dear [manager/president/etc],

We are in the process of recruiting participants for an exciting study titled 'The Modern Bodybuilder: Physiology, psychology and body composition changes in preparation for a bodybuilding competition.' The overall aims of the study are to assess and describe the diet, training and supplement practices, psychological traits and body composition changes in competitive natural bodybuilders during a cycle of competition preparation and recovery. As we aim to assess changes during competition preparation and recovery, we are recruiting bodybuilders who are willing to participate in the study in the prior to, and following, the ANB and INBA national contests.

We are therefore seeking your permission for the placement of the attached advertisement at your *[health club/gym/supplement store/website*] to help with the recruitment for this study and would greatly appreciate your assistance.

Please do not hesitate to contact Mr Lachlan Mitchell on 0431 363 027 (lmit5195@uni.sydney.edu.au) should you have any further inquiries.

Kind regards,

[*signature*]

Dr Helen O’Connor
Chief Investigator

Version 1

Date: 25/8/2014

APPENDIX E: PUBLISHED MANUSCRIPTS RELATED TO THIS THESIS

E1. Mitchell L, Murray SB, Cobley S, Hackett D, Gifford J, Capling L, O'Connor. Muscle dysmorphia symptomatology and associated psychological features in bodybuilders and non-bodybuilder resistance trainers. A systematic review and meta-analysis. *Sports Med* 2017; 47: 233-259. https://doi.org/10.1007/s40279-016-0564-3

E2. Mitchell L, Murray SB, Hoon M, Hackett D, Prvan T, O'Connor H. Correlates of Muscle Dysmorphia Symptomatology in Natural Bodybuilders: Distinguishing factors in the Pursuit of Hyper-Muscularity. *Body Image* 2017; 22: 1-5. http://dx.doi.org/10.1016/j.bodyim.2017.04.003

E3. Mitchell L, Hackett D, Gifford J, Estermann F, O'Connor H. Do Bodybuilders Use Evidence Based Nutrition Strategies to Manipulate Physique? *Sports* 2017; 5(4): 76. https://doi.org/10.3390/sports5040076

E4. Mitchell L, Slater G, Hackett D, Johnson N, O'Connor H. Physiological Implications of Preparing for a Natural Male Bodybuilding Competition. *Eur J Sport Sci* 2018; In Press. https://doi.org/10.1080/17461391.2018.1444095