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A Narrative Review on Female Physique Athletes: The Physiological and Psychological Implications of Weight Management Practices

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Running head: Health considerations in female physique athletes

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Abstract

Physique competitions are events in which aesthetic appearance and posing ability are valued above physical performance. Female physique athletes are required to possess high lean body mass and extremely low fat mass in competition. As such, extended periods of reduced energy intake and intensive training regimens are utilised with acute weight loss practices at the end of the pre-competition phase. This represents an increased risk for chronic low energy availability and associated symptoms of *Relative Energy Deficiency in Sport*, compromising both psychological and physiological health. Available literature suggests that a large proportion of female physique athletes report menstrual irregularities (*e.g.*, amenorrhea and oligomenorrhea), which are unlikely to normalise immediately post-competition. Furthermore, the tendency to reduce intakes of numerous essential micronutrients is prominent among those using restrictive eating patterns. Following competition reduced resting metabolic rate, and hyperphagia, are also a concern for these female athletes, which can result in frequent weight cycling, distorted body image and disordered eating/eating disorders. Overall, female physique athletes are an understudied population and the need for more robust studies to detect low energy availability and associated health effects is warranted. This narrative review aims to define the natural female physique athlete, explore some of the physiological and psychological implications of weight management practices experienced by female physique athletes and propose future research directions.

Keywords

Fat loss, low energy availability, physique events, body composition, nutrition

Background

Physique competitions are events in which competitors are judged on aesthetic appearance rather than on physical performance. Natural (*i.e.*, drug-free) physique competitions have evolved dramatically in recent years, with a growth in organisations, contests and classes (Halliday et al., 2016). The International Federation of Body Building and Fitness (IFBB) hosts over 2,000 competitions annually, in 196 affiliated countries. Approximately 1,300 female and male athletes competed at the World Fitness Championships in 2017 (Rowbottom, 2017), and this number is anticipated to increase, with around 1,000 new members joining the sport each year (Parish et al., 2010).

Female physique (FP) athletes have aspirations of achieving a lean and muscular body composition for competitive success (Halliday et al., 2016). Preparing for a natural physique competition provides a myriad of health benefits including improvement in cardiovascular status (Kistler et al., 2014; Robinson et al., 2015), muscle strength (Campbell et al., 2018), increasing feelings of accomplishment, and transient improvements in self-esteem (Aspridis et al., 2014; Baghurst et al., 2014; Probert et al., 2007). Despite these positive outcomes, numerous unfavorable effects also exist, including, but not limited to: diminished levels of reproductive hormones (Hulmi et al., 2016) and symptoms of disordered eating and eating disorders (DE/ED) (Walberg and Johnston, 1991). Available research on FP athletes reveals prolonged periods of sustained energy restriction and intensive training regimens in an attempt to acquire and maintain a lean body composition, indicating an increased risk of low energy availability (LEA) and its associated effects (Fagerberg, 2017). For a thorough understanding of the existence, aetiologies and clinical consequences of LEA, readers are directed to the review by Loucks et al. (2011).

Prolonged periods of LEA with or without disordered eating, menstrual dysfunction and low bone mineral density is termed the Female Athlete Triad (Triad), representing a medical condition observed in females who perform high levels of physical activity (Manore, 2007). In order to describe a wide range of physiological, psychological and performance-related impairments associated with LEA, the International Olympic Committee introduced the concept of Relative Energy Deficiency in Sport (RED-S) in 2014 (Mountjoy et al., 2014). Considering the health risks of RED-S, and the increasing participation of females in physique events, the purpose of this narrative review was three-fold: 1. to define the natural female physique athlete; 2. to explore the physiological and psychological implications of the weight management practices experienced by the natural FP athlete; 3. to address future research directions.

Literature Search

A literature search was conducted using databases: PubMed, Web of Science, Google Scholar, and SPORTDiscus (via EBSCO) up to 10th September 2018. Despite slight variation in the terminology used for ‘physique athlete’ in the literature, synonyms were included in the search strategy. Various combinations of the following search terms were used, for the search: ‘physique athlete’ OR ‘fitness competitor’ OR ‘bodybuilding’ OR ‘competitive body-builder’ OR ‘figure athlete’ AND (contest or competition OR dieting OR dietary intake or nutrition OR macronutrient OR micronutrient OR training OR body composition OR peak week OR practices OR weight loss OR weight regain). Several other search terms associated with health outcomes included: ‘physique athlete’ OR ‘fitness competitor’ OR ‘bodybuilding’ OR ‘competitive body-builder’ OR ‘figure athlete’ AND (energy availability, menstrual cycle OR bone, OR eating OR body image). Any additional articles relevant to the scope of this narrative review were obtained through PubMed via the function “similar articles” or from the reference lists of the included studies.

Criteria for inclusion were: *i*) studies published in English language and in peer-reviewed articles within the past 30 years (*i.e.*, theses or conference abstracts were not eligible), *ii*) studies involving human participants, *iii*) studies with participants who were specifically engaging or been engaged in physique competitions, across any category (*i.e.*, bikini fitness, wellness fitness, and figure), *iv*) studies using female participants, or studies using both female and male participants, and *v*) studies investigating at least one of the following: body composition, nutritional intake, micronutrients, training strategies, psychology, menstrual cycle, hormonal markers, bone mineral density, energy availability, and weight loss/management practices). Exclusion criteria were studies that reported use of performance-enhancing drugs, and only male participants.

Definition of the natural female physique athlete

Benjamin and Joseph Weider established the first organisation which specialised solely in bodybuilding events, known as the IFBB (Vallet, 2017). To date, the IFBB is one of the most influential amateur sports organisations in the bodybuilding sphere and is an official signatory of the World Anti-Doping Code where athletes participate in random drug testing programs, such as urinalysis and polygraph tests for prohibited substances (IFBB, 2014).

Whilst bodybuilding is traditionally a male dominated sport, the growth of female competitors has increased significantly in recent times (Spendlove et al., 2015). This growth in popularity is largely due to the introduction of new female-specific physique categories (*e.g.*, Fitness, Body Fitness and Bikini Fitness) since 1995 (Spendlove et al., 2015; Tajrobehkar, 2016). As these new categories allowed 'smaller' competitors to enter the sport, and reduced the emphasis on muscle mass, they have encouraged healthier practices, indirectly attracting more women from mainstream society than in previous decades (Tajrobehkar, 2016).

Female physique athletes are assessed on aesthetic appearance and posing ability whereby high lean body mass (LBM) and low fat mass (FM) are key markers of performance (Kleiner et al., 1994).

Competitions involve comparison rounds; wherein athletes are instructed to perform poses, and a final round; in which top ranked athletes perform an individual posing routine (Steele et al., 2018). The intricate scoring system assesses athlete features, such as symmetry, muscularity, size and presentation (*i.e.*, personal confidence, facial beauty, and skin condition) (Choi, 2003; Obel, 1996). Unlike other weight-restricted sports (*e.g.*, male bodybuilding, wrestling and boxing), in which weight categories are utilised, FP athletes are allocated to categories based on their subjective assessment of the amount of LBM and FM, and are then further sub-classified by height (Fry et al., 1991). At one end of the continuum (*i.e.*, bikini fitness), athletes typically have less LBM and higher FM, whilst at the other end (*i.e.*, physique), athletes are diametrically opposed with high LBM and a corresponding low FM (Fig.1).

[Insert Figure 1 near here]

Body composition in competition

Typically, an annual schedule for the physique athlete is divided into an off-season phase and a pre-competition phase (Hackett et al., 2013). Within the off-season phase, physique athletes manipulate resistance training variables including volume, intensity and frequency for the purpose of gaining LBM (Spendlove et al., 2015). This period can last years and is characterised by a positive energy balance, in conjunction with a high protein intake to stimulate muscle anabolism (Phillips, 2004; Campbell et al., 2018). In the pre-competition phase, the majority of athletes attempt to reduce body fat levels and preserve LBM using a combination of rigorous resistance and aerobic training, while manipulating their nutritional intake to achieve a negative energy balance (Hackett et al., 2013; Petrizzo et al., 2017). The pre-competition phase lasts between 12 and 24 weeks (Mitchell et al., 2018) and athletes are likely to compete between two to three times per year (Chappell et al., 2018). Usually, the pre-competition phase is followed by a recovery phase (a transition to off-season), during which athletes increase their total energy intake and decrease their total training load (Hulmi et al., 2016). Previous research reports the magnitude of weight loss is in the range of 6-10 kg over a 18-24 week period (Table 1). This suggests that FP athletes pursue a gradual approach to weight loss (~ 0.4 kg per week), similar to male bodybuilding and physique athletes (~ 0.6-0.8 kg per week) (Chappell et al., 2018; Kistler et al., 2014; Robinson et al., 2015; Rossow et al., 2013). In the end stages of the pre-competition phase, FP athletes achieve 8.6 - 16% body fat (Hulmi et al., 2016; Rohrig et al., 2017; Tinsley et al., 2018; Trexler et al., 2017), which is exceptionally lower than the recommended values for female athletes (Sundgot-Borgen and Garthe, 2011).

Strategies to manipulate body composition during competition week

Whilst FP athletes employ a gradual approach to fat loss, acute weight loss practices occur during the competition week (Helms et al., 2014). Peer-reviewed articles suggest fluid, salt, and carbohydrate manipulation is commonly practiced to reduce body water content in order to enhance muscle definition on competition day (Mitchell et al., 2017; Shephard, 1994). Nearly one-half of twenty-two FP athletes practiced water manipulations (36 %), whereas more than two-quarters practiced carbohydrate manipulations (77 %) (Chappell and Simper, 2018). Water loading, followed by water restriction is allegedly used to modify renal hormones and encourage urination beyond the period of increased fluid intake, resulting in reduced body water (Helms et al., 2014; Mitchell et al., 2017). The physiological effects of water loading have only been investigated in male combat sport athletes with a purpose of making-weight (Crighton et al., 2016; Reale et al., 2018), as opposed to physique athletes trying to enhance their aesthetic appearance. The acute weight loss experienced early in competition week (~7-5 days prior to competition) is likely to be mediated by glycogen depletion prior to a carbohydrate loading protocol (Chappell and Simper, 2018). Female physique athletes reduce their carbohydrate intake from 4.1- 4.5 $g \cdot kg^{-1} \cdot d^{-1}$ before entering the pre-competition phase, to 1.2 - 2.7 $g \cdot kg^{-1} \cdot d^{-1}$ at the end stages of pre-competition phase (Halliday et al., 2016; Rohrig et al., 2017). In one case, daily carbohydrate intake was reduced to ~ 0.3 $g \cdot kg \cdot d^{-1}$, three days prior to competition (Tinsley et al., 2018). From the available evidence, it appears that during the pre-competition phase, FP athletes fall considerably below the carbohydrate recommendations for moderate volume training (5-7 $g \cdot kg^{-1} \cdot d^{-1}$) (Manore, 2002). Addressing the distribution of carbohydrate intake throughout the day and in relation to training, could provide further insights into the strategies used to optimise body composition (Slater and Phillips, 2011).

Based on limited data, the efficacy and safety of competition week strategies in physique events are still unknown, but might be detrimental to athlete health (Chappell and Simper, 2018; Helms et al., 2014) by increasing the risks associated with hyponatremia and glycogen depletion (Slater and Phillips, 2011).

Health implications for the female physique athlete

Physique athletes typically reduce their total energy intake to induce gradual weight loss over a prolonged period of time, and progress towards acute weight loss methods, such as restrictive diets (energy availability [EA] < 30 $kcal \cdot kg^{-1}$ $FFM \cdot d^{-1}$, where FFM = fat free mass), in the latter stages of the pre-competition phase (Sundgot-Borgen et al., 2013; Fagerberg et al., 2017). As such, FP athletes face major health-related challenges in an attempt to reach and maintain a lean body composition.

Reduced energy availability in female physique athletes

Current literature on FP athletes has documented prolonged periods of LEA, specifically during the pre-competition phases. Halliday and colleagues (Halliday et al., 2016) showed that during a 20-week pre-competition phase, the estimated mean EA was categorised as low in the initial (27.9 $kcal \cdot kg^{-1}$ $FFM \cdot d^{-1}$) and latter (23.3 $kcal \cdot kg^{-1}$ $FFM \cdot d^{-1}$) stages of the phase, respectively. In this study (Halliday et al., 2016), total energy intake and exercise energy expenditure were self-reported and reproductive function was not measured. Similarly, Tinsley et al. (2018) documented caloric intakes of between 18.2 and 31.1 $kcal \cdot kg^{-1}$

$\text{FFM}\cdot\text{d}^{-1}$ in a FP athlete (during two different pre-competition phases) indicating extreme caloric restriction (Manore, 2002). Although EA was not objectively quantified, the authors estimated that the athlete fell below the threshold of EA for the maintenance of normal physiological function based on total energy intake and body composition data. Self-report research designs are not uncommon in the literature on physique athletes and, as such should be interpreted with caution (Fagerberg, 2017). Therefore, EA data in FP athletes remains questionable considering the lack of sensitive and relevant screening tools (Heikura et al., 2018). Nonetheless, aforementioned studies highlight that FP athletes may induce sub-optimal EA and shows the importance for future studies on this topic to utilise more robust measures of total energy intake and exercise energy expenditure in order to accurately evaluate EA (Elliott-Sale et al., 2018; Fagerberg, 2017).

Nutrient deficiency

Bodybuilding diets are traditionally characterised as restrictive and monotonous, as they often limit food variability (Kleiner et al., 1994). As a consequence, compromised micronutrient status is often observed in the pre-competition phase among FP athletes (Slater and Phillips, 2011). Calcium, iron, zinc and sodium intakes have been shown to decrease significantly, to less than two-thirds (~ 67%) of the Recommended Daily Allowance (RDA) (Newton et al., 1993; Walberg-Rankin and Gwazdauskas, 1993) in the absence of dietary supplements during the pre-competition phase. These results may be attributed to restricted energy intake combined with the elimination of sodium and dairy products from the diet (Steen, 1991). Considering that weight loss trends/dietary fads typically change over time, it is worth noting that the applicability of the aforementioned studies might be limited (Spendlove et al., 2015).

More recently, Ismaeel et al. (2017) showed that FP athletes who used extreme restrictive eating patterns consumed significantly less protein (123.3 ± 22.9 g *cf.* 64.8 ± 16.2 g, $p = 0.02$), sodium (4,059.6 ± 397.0 mg *cf.* 2,635.9 ± 1,028.3 mg, $p = 0.03$), vitamin E (9.9 ± 2.1 mg *cf.* 5.8 ± 1.2 mg, $p = 0.03$) and vitamin C (169.5 ± 47.4 mg *cf.* 65.5 ± 26.5 mg, $p = 0.02$) than athletes who permitted dietary flexibility (Ismaeel et al., 2017). These differences may be caused by the large variation in total energy intake (1,964.9 ± 258.9 $kcal \cdot d^{-1}$ *cf.* 1,454.7 ± 541.4 $kcal \cdot d^{-1}$) consumed by each group. While the study (Ismaeel et al., 2017) included dietary supplements in the micronutrient analysis, it did not specify whether individuals were in the pre-competition or off-season phase. Nevertheless, these results identify potential risks for deficiencies in essential nutrients for FP athletes, thereby suppressing the immune function and causing increased susceptibility to illnesses and infections, especially for those engaging in restrictive eating patterns (Sundgot-Borgen and Garthe, 2011). As the majority of studies assessing micronutrient status have also used self-report methods (Ismaeel et al., 2017; Kleiner et al., 1994; Newton et al., 1993; Walberg-Rankin and Gwazdauskas, 1993; Walberg and Johnston, 1991), it is prudent that future measures are clarified using biomarkers in blood or urine samples.

Menstrual irregularities, endocrine effects and bone health in female physique athletes

Many active women with LEA develop various forms of reproductive dysfunction, including oligomenorrhea, amenorrhea and luteal phase defects (Manore, 2002). Low energy availability causes alterations in the hypothalamic-pituitary-ovarian axis, namely diminished secretion of luteinizing hormone and follicle stimulating-hormone, which subsequently reduces oestrogen production. The final consequence is typically described as functional hypothalamic amenorrhea (West, 1998). Previous research has shown that 82-86% of females (non-contraceptive users) who entered at least one physique competition were either oligomenorrheic or amenorrheic (Walberg-Rankin and Gwazdauskas, 1993; Walberg and Johnston, 1991). Similarly, case studies have also observed amenorrhea (Hulmi et al., 2016; Petrizzo et al., 2017; Rohrig et al., 2017), with some reporting delays in menstruation of up to 71 weeks post-competition (Halliday et al., 2016; Kleiner et al., 1994; Kleiner et al., 1990).

Changes to reproductive and metabolic hormones in FP athletes have been observed in the pre-competition phase, including decreases in oestradiol, testosterone, thyroid stimulating hormone, triiodothyronine (T3) and leptin (Table 1). These hormones were normalised within 4 - 16 weeks post-competition, when supported by an increased intake of protein (~ $2.g \cdot kg^{-1} \cdot d^{-1}$) and greater EA (Hulmi et al., 2016; Trexler et al., 2017) with the exception of serum T3 and testosterone (Hulmi et al., 2016), which were only partially recovered 12-16 weeks after competition. As such, the suppression of these key metabolic hormones persist further into the recovery phase, possibly due to the effects of dropping below the EA threshold regardless of altered exercise regimen, as previously described by Loucks and Heath (1994). More longitudinal data is required on endocrine and metabolic function beyond the 16 weeks post-competition to better understand the time-course for full restoration.

Regular menstrual cycles are often used as a surrogate marker of long-term LEA; however, the use of hormonal contraceptives may obfuscate this relationship (Heikura et al., 2018). Hormonal contraceptives provide negative feedback to the hypothalamus and pituitary glands, leading to suppression of follicle stimulating-hormone, luteinizing hormone and gonadotropin-releasing hormone, and continuous down-regulation of endogenous oestrogen and progesterone (Elliott-Sale et al., 2013). Previous data in FP athletes have failed to investigate female sex hormones (*i.e.*, oestrogen and progesterone) (Trexler et al., 2017), did not include hormonal contraceptive users (Halliday et al., 2016; Rohrig et al., 2017; Tinsley et al., 2018) or grouped all oral contraceptive users together, making the interpretation difficult (Elliott-Sale et al., 2013). Considering the high prevalence of hormonal contraceptive use (Hulmi et al., 2016), there is great concern that FP athletes, who are experiencing chronic LEA, are going undetected, as hormonal contraceptive use maintains regular menstrual cycles. To this end, there is a need for studies to determine whether the FP athletes, who are using hormonal contraceptives, are at increased risk of endocrine dysfunction.

Although it is not unusual for bone mineral density to be compromised during calorie restriction and reduced body mass, it is possible that the minimal changes observed in bone mineral density (1.062-1.204g.cm^3)

(Van der Ploeg et al., 2001; Hulmi et al., 2016; Petrizzo et al., 2017) is explained by the high-impact and weight-bearing activities performed in their training regimens (Zanker et al., 2004). As a result, this may have served to retain bone-mineral density compartment (Layne & Nelson, 1999).

Weight cycling

Female physique athletes often experience rapid weight gain following competitions (Andersen et al., 1995; Walberg-Rankin and Gwazdauskas, 1993) with one study reporting uncontrollable binge eating behaviour, reflecting a hyperphagic effect to intensive weight loss protocols (Trexler et al., 2017). This practice is commonly known as 'weight cycling' (*i.e.*, repeated cycles of weight loss and regain). Previous research has reported unfavorable metabolic parameters including a decline in resting metabolic rate (RMR) (reduced between 154.7 and 226 kcal) (Rohrig et al., 2017; Tinsley et al., 2018) during pre-competition phase and weight regain of up to 8.6 kg at 4 weeks post-competition refeeding in females (Walberg-Rankin and Gwazdauskas, 1993). The RMR suppression is possibly induced by the dietary restriction during weight loss resulting in alterations in leptin levels, thyroid status and sympathetic nervous system activity (Stiegler and Cunliffe, 2006). Conversely, recent case studies have shown that some FP athletes use a "reverse dieting" technique, in order to avoid those implications (Trexler et al., 2014). This strategy requires athletes to slowly increase their energy intake in an effort to limit any rapid increases in FM, and to prevent reductions in RMR (Trexler et al., 2014). However, the effort to "reverse" (*i.e.*, slowly increase) energy intake requires considerable discipline to curb with the increases in appetite sensations (Greenway, 2015), and therefore the authors speculate, whether such a strategy is achievable. Future research on "reverse dieting" technique in the recovery phase is warranted.

Disordered eating /Eating Disorders behaviours

Considering that appearance is a major criterion to judge performance of FP athletes, the increased risk of DE/ED in this population is perhaps unsurprising. Important risk and trigger factors of poor eating habits in FP athletes may include the focus on aesthetic appearance as the primary performance marker in competition (Sundgot-Borgen and Torstveit, 2004), the peer/media pressure which can elicit body dissatisfaction (Hausenblas et al., 2013) and the influences from coaches with inadequate nutrition knowledge (Sundgot-Borgen, 1994). There is also evidence that FP athletes are particularly vulnerable to DE/ED and body image dissatisfaction because of the preoccupation with being muscular and lean (Devrim et al., 2018).

For example, a cross-sectional study by Walberg and Johnston (1991) compared 12 aspiring and retired FP athletes with 103 recreational weight-lifters on the Eating Disorder Inventory. Results revealed that FP athletes had significantly greater food obsessions (67%), uncontrolled urges to eat (58%) and felt more terrified of becoming fat (58%; all $p < 0.05$). The use of laxatives, for weight loss, (17% *cf.* 15%) and binge eating (50% *cf.* 62%) were similar between the groups.

In another study, Andersen et al. (1998) reported that ten out of twenty-six FP athletes experienced binge eating episodes in the recovery phase, and eighteen out of twenty-six FP athletes displayed body and weight dissatisfaction, reiterating that there is a high risk of eating and body image-related problems within the sport (Pope et al., 1997). Nevertheless, the small sample size and the lack of any comparative group analysis by Andersen et al. (1998) somewhat limits the interpretation. To the authors' knowledge, no quantitative data examining disordered eating behaviours exists for a large cohort of natural FP athletes.

Furthermore, it is difficult to capture sensitive data using questionnaire methods concerning mental health and well-being without a confirmatory interview (Andersen et al., 1998). Athletes may be anxious of revealing inappropriate eating practices in fear of being negatively judged, which could prevent honest disclosure. Nevertheless, there is a plausible link between participation in physique sports and DE behaviours. Further research is warranted to explore the psychopathological and behavioural outcomes in these athletes. Understanding the experiences and perceptions of weight management and eating behaviours across the pre-competition, recovery and off-season phases might be of particular importance. Using validated screening tools to detect DE and EDs and follow-up interviews will allow researchers to collect comprehensive data that could inform practice.

Conclusions and future research

The ultimate determinant of competitive success in physique events is a high degree of muscularity and minimal levels of body fat. As such, physique athletes engage in both prolonged energy restriction and intensive training regimens in order to meet these demands. Some FP athletes may be vulnerable to chronic LEA and associated physiological and psychological health effects, even during the recovery phase. Despite an increased participation in physique events, there is paucity in the literature on FP athletes. Future research should therefore:

i) identify the weight loss strategies and DE/ED behaviours of FP athletes, in order to determine the risks of LEA in this population;

ii) explore such strategies using a qualitative approach, to enable FP athletes to express and elaborate on their experiences of weight management, eating behaviours and psycho-physiological health implications;

iii) investigate endocrine and micronutrient changes in FP athletes using objective biomarkers, to assess whether these individuals are in chronic states of LEA throughout the season;

iv) develop effective, safe and evidence-based nutritional recovery guidelines to minimise any long-term health implications.

Practical Application Statement

At present, it is difficult to draw upon practical applications from the existing literature. FP athletes are an understudied population, and methodological limitations exist. A primary issue is that the majority of cited reports are case studies, or observational studies with small sample sizes, which may be insufficient for drawing definite conclusions on the possible physiological and psychological health implications among natural FP athletes. More research will have a valuable impact upon the advice and strategies provided by coaches and sport science/health professionals who work with these athletes.

It is worth noting that many female athletes are reluctant to discuss their competition strategies and health histories with health or sport science professionals (Manore, 2002), making this population difficult to research (Aspridis et al., 2014), and may explain the small sample sizes reported by previous studies (Halliday et al., 2016; Ismaeel et al., 2017; Petrizzo et al., 2017). Therefore, it is imperative that both coaches and sport science/health professionals working in the field build trusting relationships with physique athletes and respect their desires to be lean, with a view to achieve an optimum body composition and health outcomes through a collaborative relationship.

Novelty statement

This is the first review to summarise the common physiological and psychological health implications among female physique athletes.

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Author's contributions

The lead author on this paper was NA. SM, KE-S, ID and KE participated in the drafting of the manuscript. All authors read and approved the final manuscript.

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The authors declare that they have no conflicts of interest

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Table 1: Overview of the recent studies of reproductive health of female physique athletes.

Study	N	Body weight change (Body Fat %)		Time period (weeks)	TEST		E_2		T_3		T_4		CORT		Ghrelin		LP		TSH		IN		Method for menstrual status	Absence of menstruation	Bone mass density (DXA)
		CP	**RC**		**CP**	**RC**	**CP**	**RC**	**CP**	**RC**	**CP**	**RC**	**CP**	**RC**	**CP**	**RC**	**CP**	**RC**	**CP**	**RC**	**CP**	**RC**			
Haliday et al. 2016	1 ♀	-8.3kg; (15.1-8.6%)	+5.2kg; (8.6-14.8%)	20 CP; 20 RC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Self-report	9 weeks pre- and up to 71 weeks post-competition	NA
Hulmi et al. 2016	27 ♀	-7.8kg (23.1-12.7%)	+6.1kg (12.7-20.1%)	20 CP; 17.5 RC	↓	(↑)	↓	↑	↓	(↑)	↓	↑	-	-	-	-	↓	↑	↓	↑	-	-	Serum and self-report	11.5% pre-competition and 28% post-competition	↓CP; ↑RC
Trexler al. 2017	8 ♀ 7 ♂	-	+3.9kg (12.5-14.9%)	4-6 RC	-	↑		-		-		-		↑↓		↑		↓	-	-	-	↑	Saliva	-	-
Petrizzo et al. 2017	1 ♀	-7.7kg (24.4-11.3%)	-	24 CP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Self-report	Oligomenorrhea	No change
Rohrig et al. 2017	1 ♀	-10.1kg (30.5-15.9%)	-	24 CP	↑↓	-	↑↓	-	-	-	-	-	↑↓	-	-	-	↓	-	↓	-	-	-	Serum and self-report	8 weeks pre-competition	-
Tinsley et al., 2018	1 ♀	-6 kg (20.3-11.6%)	+6.8kg (11.6-18.8%)	18 CP (1) 7 CP (2) 9 RC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Self-report	12 weeks pre-competition (1) and up to 12 weeks post-competition (2)	NA

♀ indicates female physique athletes, ♂ indicates male physique athletes, ↑↓ indicates fluctuation, CP indicates the pre-competition phase, RC indicates recovery phase, ( ) indicates not recovered to initial baseline values, (1) indicates 1st competition and (2) indicates a 2nd competition. TEST = Testosterone, E2 = Estradiol, T_3 = Triiodothyronine, T_4 = Thyroxine, CORT = Cortisol; TSH= Thyroid stimulating hormone; LP= Leptin, IN = Insulin; DXA = Dual-energy X-ray absorptiometry. NA = Information not available.

Figure 1: An overview of the current female categories in women's physique competitions. The categories are progressive steps along a continuum between lean body mass and fat mass. 'Dry' refers to dehydration and the subsequent reduction in body water (Chappell et al., 2018). The number of height classes in each category is determined by the popularity of the single category. This figure was drawn using information retrieved from the International Federation of Bodybuilding and Fitness website (FBB Elite Pro Categories, 2017).