NORWEGIAN SCHOOL
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Resting Metabolic Rate in Female Fitness Athletes before, during and after Fitness Competition

A prospective cohort study investigating the consequences of dieting on RMR

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Abstract (ENG)

Objectives: Body image idealization and appearance is a never-ending debate in society. The past five to eight years a rapid increase in popularity in competitions focusing on body, muscle development and appearance, such as different fitness categories has been observed. Yet, there is lack of research and knowledge on health effects from such a lifestyle. Hence, the aim of this study was to examine if four months of dieting leading up to a fitness competition leads to any change in RMR in female fitness athletes, and whether or not any potential change in RMR will be reversed when the fitness athletes returns back to their normal diets.

Methods: Data used in this study was collected from a larger research project named "Fitness Health", a prospective cohort study examining the effect of a fitness lifestyle on competitive female fitness athletes. A physically active, age matched, female population was recruited as a control group. RMR was measured through indirect calorimetry, at three points; 1) before their preparatory diet was initiated (3-4 months pre-contest), 2) two weeks prior to the contest and 3) one-month post competition. A final sample of 46 participants, n=22 Fitness athletes and n=24 physically active controls were included in the study.

Results: A significant decrease (-184 ±46 kcal/day, $p=.002$) in RMR was detected after four-months of dieting in female fitness athletes. One-month post competition RMR was increased compared to 2 weeks pre contest (326 ±74 kcal/day, $p=.001$). There was no significant difference in mean RMR one-month post competition compared to baseline ($p=.294$). No significant effect over time in mean RMR was found in PA controls ($p=.174$).

Conclusion: A significant change in RMR was observed in fitness athletes after four months of dieting leading up to a fitness competition. However, one-month after competition RMR values were reversed back to baseline levels.

Abstract (NO)

Hensikt: Kroppsidealer og utseende er en uendelig debatt i samfunnet. De siste fem til åtte årene har konkurranser som fokuserer på kropp, muskel utvikling og utseende, slik som ulike grener av Fitness opplevd en voldsom økning i popularitet. Likevel er det mangel på forskning og kunnskap vedrørende helseeffekter av en slik livsstil. Derfor er hensikten med denne studien å undersøke om fire måneder på en konkurranse forberedende diett fører til endringer i hvilemetabolisme hos kvinnelige Fitness utøvere, og om en eventuell endring i RMR vil returnere når utøvere går tilbake til normalt kosthold.

Metode: Data brukt i denne studien er samlet inn i forbindelse med et større forskningsprosjekt kaldt "Fitness Helse", en prospektiv kohort studie som undersøker effekten av en Fitness livsstil, både fysisk og psykisk hos kvinnelige konkurransedyktige Fitness utøvere. En gruppe med fysisk aktive, jevnaldrende kvinner ble rekruttert som kontrollgruppe. RMR ble målt ved indirekte kalorimetri ved tre ulike måletidspunkter; 1) før utøverne startet på diett (3-4 mnd i forkant av konkurranse), 2) to uker før konkurranse og 3) en måned etter konkurranse. Et utvalg på totalt 46 deltagere, n=22 Fitness utøvere og n=24 fysisk aktive kontroller deltok i studien.

Resultater: En signifikant reduksjon i RMR (-184 ±46 kcal/dag, p=.002) ble observert etter fire måneder på konkurranse forberedende diett hos kvinnelige Fitness utøvere. En signifikant økning i RMR ble oppdaget en måned etter konkurranse sammenlignet med to uker før konkurranse (326 ±74 kcal/dag, p=.001). Det var ingen signifikant forskjell i gjennomsnittlig RMR en måned etter konkurranse sammenlignet med baseline (p=.294). Ingen signifikant endring over tid i gjennomsnittlig RMR ble funnet hos fysisk aktive kontroller (p=.174).

Konklusjon: Fire måneder med konkurranse forberedene diett førte til signifikant reduskjon i RMR hos kvinnelige fitness utøvere. RMR returnerte derimot tilbake til baseline verdier en måned etter siste konkurranse.

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Abbreviations

BMI:	Body mass index
BMR:	Basal metabolic rate
BW:	Body weight
%BF:	Percentage of body fat
DC:	Direct calorimetry
FFM:	Fat free mass
FM:	Fat mass
HR:	Heart rate
IC:	Indirect calorimetry
IFBB:	International Federation of Bodybuilding & Fitness
MM:	Muscle mass
mRMR:	Measured resting metabolic rate
NKF:	Norwegian National Federation for Bodybuilding & Fitness
NSSS:	Norwegian School of Sport Sciences
PA:	Physical activity
PAcontrols:	Physically active controls
pRMR:	Predicted resting metabolic rate
RMR:	Resting metabolic rate
RMRratio:	The ratio between measured and predicted resting metabolic rate
SD:	Standard deviation.
TDEE:	Total daily energy expenditure
TEI:	Total energy intake
WL:	Weight loss
WR:	Weight regain

1.0 Introduction

Body image idealization and appearance is a never-ending debate in society. Body ideals are constantly evolving and changing, and people have been exposed to it by all times (Boyd & Murnen, 2017). The skinny ideal appeared for the first time in the 1960s (Boyd & Murnen, 2017). The ideal of thinness was first about dieting, but throughout the 80s, when people started jogging, and a decade later, with fitness industry getting a foothold, it was more acceptable for females to exercise and have a more toned, athletic body (Markula et al., 2001). Fit became the new skinny, and the ideal changed from being thin to more athletic (Simpson & Mazzeo, 2016). Nowadays, the weightlifting areas at the gyms are no longer only occupied by men. The myth stating that strength training only leads to a masculine body shape has been rejected, and strength training has become increasingly more popular also among females (Vaage, 2015). The emergence of social media has led to greater exposure of apparently «perfect» bodies (Jacobsen, 2016). Slogans such as "fit is the new skinny", "clean eating" and "healthy living" are often seen together with pictures of beautiful, well-defined and muscular women (Halvorsen, 2015). #Fitness has been used over 200 million times on Instagram and is among one of the most used hash tags (Top-hashtags, n.d). The extent of all these apparently "perfect" bodies and slogans gives an illusion that exercise and healthy eating is crucial to be perceived attractive and successful. In a world and a time span, where young individuals in particular, are exposed to expectation of success in all areas in life, this illusion may contribute to a perceived assumption of failure (Tiggemann & Zaccardo, 2015). According to Aasen & Fjellstad (2007) in modern society, the body not only has to be slim, but also athletic to be considered and appear as healthy.

The past five to eight years, in parallel with the increased access and exposure of body ideals through social media, various competition arenas have been developed to cultivate this interest (IFBB, n.db). Competitions focusing on body, muscle development and appearance are not revolutionary, as bodybuilding has existed since the early 1900s (Schwarzenegger, 1999). However, this has been a small and somewhat isolated culture in the big world of sports. In the late 90s a couple of new lightweight classes emerged, and during the last couple of years different fitness branches emphasizing less definitions, volume and vascularity, but worship a softer, yet muscular and toned feminine body has become increasingly popular (IFBB, n.db). These fitness branches seem to appeal more to women who enjoy exercise and like to keep in shape, and because of its absence of requirements of what has traditionally been seen as a more masculine muscle size and heavy lifting, these new branches opens up for a much larger share of participants. In the Norwegian fitness contest “Oslo Grand Prix” 2018; a total of 181 female fitness athletes attended the contest, whereas 134 engaged in bikini fitness and 47 in bodyfitness (Oslo Grand Prix, 2018). This is quite an increase from “Sandefjord Open” in 2013, where only 10 and 7 female competitors were registered to attend in respectively bikini fitness and bodyfitness (Sandefjord-Open, 2013).

Despite the rapidly increase in popularity for fitness competitions the last couple of years, there is lack of knowledge on health effects from such a lifestyle. Physical and psychological health effects of very strict diets combined with a high volume of training have earlier been assessed (IOC, 2005). However, in contrast to approaches previous seen and examined, fitness athletes apply new strategies where the composition of macronutrients is thoughtfully planned and controlled. In addition, emphasis is on muscle developing strength training rather than high amounts of aerobic exercise. The potential effects of this approach on the human being, both mentally and physically are unclear and needs to be further examined. A medical commission group from the International Olympic Committee (IOC) examined, among other thing, effects of low energy availability on performance and health in female athletes (IOC, 2005). The committee claims that energy intake below what is required to meet the energy cost of fundamental physiological processes and energy spent in exercise, may be detrimental to various physiological functions and health, including resting metabolic rate (IOC, 2005).

Resting metabolic rate (RMR) can be defined as the energy costs of basic physiologic functions and contribute to 60- 65% of the daily total energy expenditure (Kenney, Wilmore & Costill, 2015: Speakmen & Selman, 2003). RMR is determined by different components, where fat-free mass is seen to be the biggest contributor due to the high metabolic activity in muscular tissue (Kenney, Wilmore & Costill, 2015). Age, body surface and body temperature do also affect RMR, and RMR may also be affected or interfered with by various factors such as a varity of hormones, psychological stress and energy availability (Kenney, Wilmore & Costill, 2015). Energy availability can be explained as the amount of energy left for fundamental physiological processes, after energy expended due to exercise is subtract from dietary energy intake (Loucks et al., 2011). Physical activity and exercise leads to increased energy consumption, while restrictive diets reduce daily energy intake. Increased energy expenditure combined with reduced energy intake causes a decrease in energy availability (Loucks et al., 2011). Selective and restrictive eating behavior, strength training and use of different supplements, which in combination leads to low energy availability, characterize the fitness lifestyle, especially in the preparations for a fitness competition (Halvorsen, 2015).

It´s established that negative energy availability over time will affect metabolism (Fothergill, Guo, Howard, et al., 2016; Müller & Bosy-Westphal, 2013), and the reduction in RMR after weight loss is often greater than expected based on the changes in body composition (Fothergill, Guo, Howard, et al., 2016). However, in case of weight regain it´s uncertain whether or not RMR reverses in the same rate. Severeal researchers has investigated this relationship, yet, their findings differs. Fothergill and colleagues (2016) found that despite substantial weight regain six years after participating in “The Biggest Looser”, RMR remained suppressed at same levels as after the weight loss in 14 obese men and women. Similar results have been seen in both obese (Bosy-Westphal et al., 2013) and non-obese individuals (Kajioka et al., 2002) after weight regain following weight loss. In contrast Sagayama et al. (2014) did not find any significant change in BMR after rapid weight regain after weight loss in weight-classified athletes. In 12 weight-cycling wrestlers, Melby et al. (1989) found that despite decreased RMR during wrestling season, RMR returned back to baseline levels as a result of post-season weight regain. As such RMR may seem to adapt better to weight regain in athletes or well-trained individuals compared to overweight and obese individuals.

Little is known about the health effects following the modern idealized fitness lifestyle. The fitness approach to weight loss is a new method of manipulating weight and is different from what previously seen. These strategies are claimed to be more beneficial in terms of maintain RMR during weight loss (Helms et al., 2014b), which may impact not only the athletes, but also everyone else following this fitness regime in the pursuit of the perfect body, both physically and mentally. However, there is lack of research examining this, thus, the aim of this study is to detect whether resting metabolic rate will change as a result of four months of competition preparatory diet, and whether or not any potentional change in RMR reverses when fitness athletes returns to normal diet after participating in fitness contest.

1.1 Research Question

1. *Will four months of dieting leading up to a fitness competition result in changes in resting metabolic rate (RMR) in female fitness athletes aged 18-40 years?*

2. *Will a potential change in RMR be reversed when fitness athletes return to a normal diet after a fitness competition?*

1.1.1 Hypothesis

Research question 1:
H_o = Four months of dieting leading up to a fitness competition will not result in any change in resting metabolic rate (RMR) in female fitness athletes aged 18-40 years.

H_1 = Four months of dieting leading up to a fitness competition will result in change in resting metabolic rate (RMR) in female fitness athletes aged 18-40 years.

Research question 2:
H_0 = A potential change in RMR will be reversed when fitness athletes return to a normal diet after a fitness competition.

H_1 = A potential change in RMR will not be reversed when fitness athletes return to a normal diet after a fitness competition.

2.0 Background

2.1 Fitness

2.1.1 History

Muscle building can be dated back to the ancient Greeks and was traditionally seen as a way of compare strengt and power (Schwarzenegger, 1999). During the late 19th century a new interest in muscle building arose, where muscle development was seen as a tribute to the human body and its aesthetic beauty. The ancient stone-lifting tradition evolved into the modern sport of weightlifting, and in 1940 the Amateur Athletic Union (AAU) arranged the first modern bodybuilding contest (Schwarzenegger, 1999). A couple years later, in 1946, the International Federation of Bodybuilding and Fitness (IFBB) was founded (IFBB, 2017a). At first, bodybuilding was primarily intended men, but in 1996 the first official competition in “women´s fitness” was arranged (IFBB, n.db). Women´s fitness emphasizes a shaped, athletic physique combined with a high tempo artistic fitness routine (IFBB, n.db). In 2002, IFBB implemented a new branch for women called Womens´s Bodyfitness. Unlike Women´s fitness, bodyfitness do not have the artistic routines and was developed for females who wanted only to focus on their physique. Bikini fitness emerged as a new branch in the world of Fitness in 2010 (IFBB, 2017c). The purpose of bikini fitness was to reach women who wanted to stay fit and eat healthy. Unlike body fitness and other branches, emphasis is placed on a proportional and balanced body rather than hard and defined muscles (IFBB, 2017c). In 2013 Womens´s physique was introduced by IFBB as the latest fitness branch on the market. Women´s physique is quite similar to former bodybuilding, targeting women who want a body shape as seen by the more traditional bodybuilders (IFBB, n.db).

2.1.2 The Norwegian Bodybuilder and Fitness Federation

The Norwegian Bodybuilder and Fitness Federation (NKF) were founded in 1965 (Brønnøysundregistrene, n.d). The organization is affiliated the International Federation of Bodybuilders (IFBB) and sets the framework for competitive bodybuilding and fitness in Norway (NKF, n.da). NKF is a voluntary, politically neutral and independent organization aiming to provide bodybuilding and fitness in a healthy environment, and contribute to improving the health and well being of the population (NKF, n.da).

2.1.3 Rules and judgement

In order to participate in national competitions a membership in a club affiliated NKF is required (NKF-IFBB, n.da). According to IFBB and NKF´s regulations, use of artificial performance-enhancing supplements or methods are strictly forbidden (NKF-IFBB, n.da). Each participant is required to follow the specification regarding attire in the current competitive category (NKF-IFBB, n.da).

Further detailed information regarding specific rules and regulation can be found on NKF or IFBB´s official webpages (www.nkf-ifbb.no & www.ifbb.com/rules/).

2.1.3.1 Bikinifitness

According to the IFBB guidelines (IFBB, n.db) *"fine lines and a healthy and attractive appearance, like what is seen in models, are emphasized"*. On stage the athletes wear a two-piece bikini and high heels, within the regulations of NKF and IFBB (IFBB, 2017c). In addition to bodily appearance, hair and beauty, the athlete's self-esteem on stage, radiance, elegance and grace is evaluated. The judges will emphasize the overall body tone, with nice and firm appearance of the muscles (IFBB, 2017c). However, the physique should be softer and with a bit more body fat compared to what is seen in bodyfitness. Exaggerated muscle mass and leanness will be marked down by the judges (IFBB, 2017c). The physique and appearance should be aimed to look healthy and fit, and hair, skin tone, grace and confidence will also be taken into consideration. It is the overall assessment that ultimately determines the score and placing (IFBB, 2017c).

2.1.3.2 Body Fitness

IFBB (2017b) describe Women´s bodyfitness as *"a sport discipline for women who prefer to develop a less muscular, yet athletic and aesthetically pleasing physique"*. The judges emphasize a combination of muscles and low proportion of body fat along with attractiveness, grace and elegance (IFBB, 2017b). A healthy, proportionally and symmetrically, yet toned physique is emphasized (IFBB, 2017b). Low percentage of body fat and round and firm muscles are desirable. However, the athletes are not supposed to be excessively muscular, and too big muscle size and deep muscle separations will be marked down (IFBB, 2017b). Hair, skin, elegance and overall appearance should also be taken into account when judging. The assessment and final scoring in Women´s bodyfitness is based on the overall presentation and performance (IFBB, 2017b).

2.1.3.3 Athletic Fitness

In the Nordic countries, a separate category of fitness is included amongst the competitive classes, emphasizing athletic look but also athletic performance (NKF-IFBB, n.db). In contrast to bikinifitness and bodyfitness, the competitions in athletic fitness do also consist of two rounds of physical exercises, including chins, dips and rowing (NKF-IFBB, n.db). The attire in athletic fitness differs slightly from bikini fitness and bodyfitness. The participants must be barefoot, wearing a plain, black two-piece bikini in the first round, while they may choose a suitable outfit in the physical rounds, showing their arms so the judges can se if joints are sufficiently stretched in the implementation of the exercises (IFBB, n.da; NKF-IFBB, n.db).

In athletic fitness, participants are assessed based on muscular development, symmetry, athletic appearance, physical performance and overall performance (IFBB, n.da; NKF-IFBB, n.db). Some muscular development is necessary, however, this is not a bodybuilding contest and too much development, definition and vascularity will be marked down (IFBB, n.da; NKF-IFBB, n.db).

2.1.4 Preparations

There is great variety concerning preparation prior to a fitness or bodybuilding contest (Helms, Aragon & Fitschen, 2014b). The preparation period is normally 2-4 months; however, the duration varies considerably (Helms, Aragon & Fitschen, 2014b; Lambert, F& Evans, 2004). The purpose of the pre-contest period is to achieve a drastic reduction of body fat, while maintaining muscle mass (Helms, Aragon & Fitschen, 2014b; Lambert, F& Evans, 2004). There are different approached to achieve this, nonetheless, restrictive diets with reduced energy intake along with increased energy expenditure through intense resistance training and increased cardiovascular exercise is a common denominator for most of the strategies (Helms, Aragon & Fitschen, 2014b). Recommendations and guidelines for optimal contest preparation in Fitness are lacking. Thus, there is great variation in the scientific evidence of the different approaches, where some are strongly supported in the literature, while others not.

To achieve weight loss and reduction in body fat, it is crucial to spend more energy than what is consumed (Helms et al., 2014b). Calorie reduction is a key part of a fitness diet. As greater energy deficits cause rapid weight loss, and rapid weight loss yields greater loss of FFM (Helms et al., 2014b), one can assume that moderate calorie restriction might be beneficial for fitness athletes in pre-contest period. Energy restriction is associated with different metabolic and psychological changes, including hormonal changes, which may be detrimental for female atheltes (Rankin, 2002). Thus, gradual weight loss is proposed to be preferable to maintain good health in athletes. Rankin (2002) suggests a modest calorie deficit of 500 kcal/day to achieve healthy weight loss in athletes. Helms and colleagues (2014b) suggest in their systematic review a calorie reduction in which results in a weight loss of 0.5-1.0% BW per week when the diet period is lasting for more than 2-4 months to prevent severe loss of FFM.

As maintenance of muscle mass is a primary concern during contest preparation, it is desirable that calorie reduction to a small extent occurs from proteins, to prevent loss of MM (Helms, Aragon & Fitschen, 2014b). It´s established that strength athletes might benefit from higher intake of protein to support muscle growth (Lambert, Frank & Evans, 2004; Phillips, Moore & Tang, 2007; Phillips & Van Loon, 2011). A protein intake of 1.2-2.2 g/kg is suggested to be sufficient in athletes at or above energy needs (Phillips, Moore & Tang, 2007; Phillips & Van Loon, 2011; Tarnopolsky, 2008), however, a higher protein requirement is suggested for leaner individuals and athletes in energy deficit (Mettler, Mitchell & Tipton, 2010; Phillips & Van Loon, 2011). Helms and colleagues (2014a) did a systematic review of dietary protein during caloric restriction in resistance trained lean athletes, and suggested a rage of 2.3-3.1 gram protein per kg lean body mass. These recommendations may be more suitable for fitness athletes to maintain FFM during the preparation period, as calorie restriction, resistance training and a lean body characterize the regimen prior to a fitness contest. Protein does also require a higher amount of energy to metabolize compared to carbohydrate and fat (Lambert, Frank & Evans, 2004). Thus, a high protein diet may also be beneficial in terms of increased termic effect from food, and hence to promote fat loss, along with the maintenance of MM (Lambert et al., 2004).

According to Lambert and colleagues (2004), fitness athletes should include adequate amount of carbohydrate (55-60% of total daily energy intake) in their diet in the pre-contest phase to ensure sufficient training intensity. Adequate carbohydrate consumption may reduce degree of glycogen depletion and sustain exercise quality, and thus enhance performance (Helms et al., 2014b). Even though the contribution of protein and carbohydrates are most emphasized in fitness athletes' preparatory diets, fat also is an essential macronutrient. Lambert and colleagues (2004) suggest that 15-20% of total daily energy intake should come from fat both off-season and during pre-contest period. This statement is further supported by Helms and colleagues in their systematic review (2014b). High protein, low fat diets with adequate levels of carbohydrate appears to be more effective at maintain muscle mass in resistance trained athletes undergoing calorie restrictions compared to high fat, low carb diets (Helms, Aragon & Fitschen, 2014b).

Reduction in energy intake should diminish as the competition approaches, to preserve MM. This is due to higher muscle loss when there is a decrease in available adipose tissue (Helms, Aragon & Fitschen, 2014b; Lambert, Frank & Evans, 2004). Helms et al. (2014b) suggest a reduction in energy deficit when the athlete has reached her desired body composition to prevent loss of MM.

Supplements are often seen as a natural part in fitness athletes´ diets prior to competition. Yet, it is questionable whether these supplements contribute to increased performance or improved appearance. Supplements like caffeine, creatine and beta-alanine are commonly used by fitness athletes, and according to Helms et al. (2014b), these supplements seem to have beneficial effects on fitness athletes in terms of increasing muscle size and muscle strength, extend time to fatigue and improve workload as well as performance. The effect on other commonly used supplements as BCCA´s (branched chain amino acids), glutamine, arginine and HMB (Beta-hydroxy-beta-methylbutyrate) is unclear, whereas some are suggested not to have any beneficial effect, while others need more research (Helms et al., 2014b).

In terms of exercise during the pre-contest period, fitness athletes are recommend to continue with the same resistance exercise regimen as off-season and attempt to maintain sets, repetitions and resistance as far as possible (Lambert, Frank & Evans, 2004). Furthermore, reduction in body fat should arise from increased aerobic exercise and energy restriction, rather than high repetition and low resting periods during resistance workout (Lambert et al., 2004).

The last week before competition, called “peak week”, there is a noticeable change in the diet. In the beginning of peak week, carbohydrates are often eliminated from the diet (Helms et al., 2014b). Carbohydrates bind water (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015**)**, and thus, elimination of carbs is suggested to drain body water. In attempt to increase muscle-glycogen and muscle size, carbohydrate loading is often seen the last few days before competition (Helms et al., 2014b; Hulmi et al., 2016). The first days of carbohydrate loading, water intake continues as usual. As carbohydrates bind with water as it enter muscular tissue, the muscles appear to be more voluminous and bulky. The last 24 hours, the athletes totally refrain from water (Helms et al., 2014b). By cutting the water the last 24 hours, one may be able to drawn fluid out of the subcutaneous tissue, such that muscle definitions and blood vessels appear even more visible in the skin surface. The last few minutes before entering the stage, light and repetitive weight lifting (elastic bands are often used) is common practice to increase blood flow and thus increase physique appearance due to more defined muscles (Helms et al., 2014b).

2.1.5 Competition

The Norwegian Bodybuilding and Fitness Federation (NKF) arrange fitness and bodybuilding contests during spring and autumn every year. January to July is considered spring season, while fall season extends from August to December (NKF-IFBB, n.dc). During spring season the athletes compete in “Sandefjord Open” and “Oslo Grand Prix”, while “Sandefjord Open” and “Norwegian Championchip” is arranged in the autumn (NKF- IFBB, n.dc). NKF reserves the right to select classes and categories in each contest based on participation and the time frame of the competition, and all branches and categories listed in the IFBB´s regulation may therefore not be represented (NKF-IFBB, n.dc). Placing in national competitions is crucial for qualifying to international competitions. The competitors are required to qualify in the same category they want to compete in internationals (NKF-IFBB, n.dc).

The day before the competition all competitors must register and weigh in to make sure they meet NKF´s criteria for participation (NKF-IFBB, n.dd). The height is measured to ensure that the athlete is registered in the correct height class. The athletes are required to wear the attire they intend to use on stage. If the equipment does not meet the requirements, the athlete must obtain another bikini or set of shoes that meet the criteria to be allowed to compete (NKF-IFBB, n.dd). Consumption of alcohol or drugs is strictly prohibited at the arena (NKF-IFBB, n.dd). A time schedule is provided and each athlete is responsible for entering the stage at the given time. When there are more than 15 competitors participating in one class, elimination rounds will be held (NKF-IFBB, n.dd).

2.1.6 After competition

Weight regain after weight loss is a common phenomenon. Diet induced weight loss leads to a variety of biological responses, much like symptoms of starvation, such as reduced sensitivity to satiety, elevated appetite and cravings, and thoughts circulating about foods (MacLean et al., 2011; Melby et al., 2017). Changes in hunger and satiety after weight loss is associated with weight regain (Melby et al., 2017). However, after a fitness competition, weight regain is desirable, and the athletes should aim to gradually increase BW back to off-season levels (Hulmi et al., 2016). The biological drive to weight regain is highly applicable to fitness athletes after a long period of dieting and calorie deficiency. The increased sensation of hunger and cravings may lead to uncontrolled and excessive overeating, which could further lead to abnormal rapid weight gain (Melby et al., 2017). This may potentially have negative metabolic and psychological impact on the athletes (Rankin, 2002). A healthy and gradual weight regain may therefore be preferable (Rankin, 2002).

“Reverse diet” is often used among Fitness athletes in the period following competition to control and slow down the weight regain (MacLean et al., 2011). The concept of reverse dieting is to gradually add calories back into the diet to increase metabolism. To prevent storing too much body fat and water retention, it is crucial to increase metabolism and restore hormone levels over time by gently and systematically adding more energy to the diet, rather than ad libitum eating (MacLean et al., 2011). The composition of the diet is also essential for a reverse diet to be successful. A healthy composition of macronutrient with adequate amount of carbohydrate (60-65% of TEI) and protein (15% of TEI), along with physical activity and exercise, are suggested to be beneficial to acchive gradual and healthy weight regain in athletes (Ranking, 2002). In order to gain weight, energy intake must be greater than consumed (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015). Rankin (2002) suggest a modest energy surplus of 500 kcal/day to be optimal for health enhancing weight regain in athletes. This will result in a weight gain of 0.5-1 kg per week, which is suggested to be beneficial to maintain health (Rankin, 2002). The athletes´ health should be the main focus in the development of such diets, and Ranking (2002) highlights the importance of educated personnel to ensure safe approaches that will not be harmful or have negative effect on the athletes´ health.

2.2 Resting metabolic rate

2.2.1 Definition

To sustain vital functions each individual requires a minimum amount of energy (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015; Pinheiro Volp et al., 2011). This energy requirement is termed as basal metabolic rate (BMR) (McArdle, Katch & Katch, 2015). Harris & Benedict (1918) define basal metabolic rate as "*The heat production of the individual in a state of complete muscular repose 12-14 hours after the last meal, i.e, in the post absorptive condition".* BMR is measured under stringent laboratory conditions, after a minimum of 12 hours of fasting and 8 hours sleep (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015; Pinheiro Volp et al., 2011). To ensure basal metabolic values are measured, the subject is required to sleep overnight at the measurement venue (Pinheiro Volp et al., 2011). There are some practical limitations with BMR measurement, due to its strict testing protocol. Resting metabolic rate is therefore more commonly used to detect metabolism during rest in most research (Kenney, Wilmore & Costill, 2015; Pinheiro Volp et al., 2011). Compared to BMR, RMR is measured in less stringent standardized condition.

Due to the different requirements in advance of the measurement, BMR and RMR values can differ between 5-10%, where BMR always are slightly lower than RMR (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015; Pinheiro Volp et al., 2011; Psota & Chen, 2013). Despite the small difference, both methods are still considered to be highly valid and reliable (McArdle, Katch & Katch, 2015). The terms are often used alternately, but it's important to be aware of the difference, especially when comparing studies and results where BMR and RMR are used interchangeably. According to Kenney and his colleagues (2015) BMR ranges from 1100-2500 kcal/day dependent on age, body mass, body surface, etc. Based on Harris Benedict equations for RMR, the average RMR for non-obese women between 18-40 (based on mean scores in age, height and BW from participants in the present study) are 1440 Kcal/day (Harris &

Benedict, 1918). Metabolic rate at rest is together with thermic effect of food and energy expenditure from physical activity, one out of three components that outlines total daily energy expenditure (TDEE), of which resting metabolic rate accounts for approximately 50-80% of the TDEE, depending on physical activity level (McArdle, Katch & Katch, 2015; Pinheiro Volp et al., 2011; Psota & Chen, 2013).

2.2.2 Components of RMR

RMR is determined by different physiological contents, where fat-free mass (FFM) is seen to be the biggest contributor due to the high metabolic activity in organs and muscular tissue (Kenney, Wilmore & Costill, 2015). According to Gallagher and colleagues (1998) up to 60% of RMR in adults is due to metabolic activity in organs such as the brain, heart, liver and kidneys, and up to 30% is due to muscular tissue. However, the organs only accounts for less than 6% of total BW, whereas skeletal muscles accounts for up to 50% of total BW (Gallagher et al., 1998). Thus, in individuals with higher share of muscle mass, the organs contribute a smaller proportion of total RMR, while muscular tissue accounts for a greater share. Due to the high metabolic activity in organs and muscular tissue, a high proportion of fat-free mass will lead to higher daily energy expenditure. Men tends to have a higher proportion of fat-free mass along with lower percentage of body fat compared to women, which can help explain why men in average has a 5-10% higher RMR than a women of similar weight and age (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015).

Age, body surface and body temperature do also affect RMR and it may also be affected or interfered with by various factors such as various hormones, psychological stress and energy availability (Kenney, Wilmore & Costill, 2015). The area of the body surface do affect metabolic rate at rest. Heat loss from the skin will vary according to the size of the skin´s surface. The larger the surface, the more heat will emit from the skin. This will affect RMR due to the increased energy desire to maintain body temperature (Kenney, Wilmore & Costill, 2015). RMR are shown to decrease throughout the life span as a result of gradually loss of fat-free mass (Kenney, Wilmore & Costill, 2015). According to McArdle and colleagues (2015) there are studies showing a 2-3% reduction in BMR every ten-year thought the lifespan. Bosy-Westphal et al (2008a) suggest 5% of inter-individual variation in RMR to be explained through age. Psychological stress does affect a variety of physiological functions in the human body.

One of the physiological processes affected by stress is RMR. The increase in RMR due to psychological stress can be explained by the increased activity of the sympathetic nervous system (Kenney, Wilmore & Costill, 2015). A varity of hormones do also have an impact on RMR and increased release of thyroid hormones or epinephrine has been shown to increase the metabolic rate at rest, even though the exact mechanism remains unclear (Aristizabal et al., 2015; Kenney, Wilmore & Costill, 2015).

2.3 Measurement of RMR

Heat production is the final outcome of every metabolic process in the body, and thus the rate of energy metabolism is defined by the rate of the heat production by cells, tissues and the whole body (McArdle, Katch & Katch, 2015). There are different ways to measure metabolic rate, either by directly measuring the heat transfer, or indirectly by measuring the amount of oxygen consumed in relation to the amount of carbon dioxide created (McArdle, Katch & Katch, 2015).

2.3.1 Direct calorimetry

Direct calorimetry (DC) measures the actual heat transfer from the cells, tissues and body to determine metabolic rate (McArdle, Katch & Katch, 2015). Direct calorimetry is normally conducted in an airtight chamber where metabolic rate is determined by measuring the amount of energy released as heat from the body over a given time period (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015). There is a tube within the walls of the chamber, where water circulates. The heat released from the subject is transferred to the walls of the chamber where the water is heated. The heat loss also affect the air temperature, and the change in temperature of the air entering and leaving the chamber will together with the temperature of the water determine the metabolic rate of the subject (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015).

Despite its accuracy, direct calorimetry is expensive and resource consuming and thus inapplicable in practice for most occasions (McArdle, Katch & Katch, 2015).

2.3.2 Indirect calorimetry

Unlike direct calorimetry, indirect calorimetry is less expensive, easier to use and less resource consuming (McArdle, Katch & Katch, 2015). Thus indirect calorimetry is more commonly used in clinical settings to determine resting metabolic rate (McArdle, Katch & Katch, 2015). In contrast to direct calorimetry that measures the heat transfer from the body, indirect calorimetry (IC) assess metabolic rate by measuring the amount of oxygen used compared to the amount of carbon dioxide produced (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015).

The human body is dependent on oxygen in order to function (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015). While breathing, there is a respiratory gas exchange in the alveoli of the lungs, where fresh oxygen (O_2) enters the blood and carbon dioxide (CO_2) returns from the blood back into the lungs (McArdle, Katch & Katch, 2015). Inhaled air consist of a higher concentration of O_2 compared to the expired air, while opposite for CO_2. The respiratory gas exchange tells us how much oxygen absorbed and how much CO_2 produced. The amount of oxygen consumed compared to the amount of carbon dioxide produced are measured through indirect calorimetry and used to determine metabolic rate (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015).

Respiratory quotient (RQ) is another term essential for measuring energy consumption. RQ is the volume of CO_2 released (VCO_2) divided on the volume of oxygen consumed (VO_2), and indicates the metabolism of macronutrients in the cells (Fullmer et al., 2015; Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015). Different substrate (carbohydrate, fat and protein) requires different amount of oxygen to be completely oxidised, and the RQ indicate which substrate is used to produce adenosine triphosphate (ATP) (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015). An RQ of 1.0 indicates that an individual is using 100% carbohydrate to produce ATP, while an RQ of 0.7 indicates that 100% of the metabolism is due to fat (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015). According to studies reviewed by Fullmer et al (2015), RQ ranged from 0.68 to 0.90 after 7 to 14 hours of fasting in advance of the RMR measurement. In cases where RQ values are <0.67 or >1.3 the clinician should consider to repeat the measurement due to error (Branson & Johannigman, 2004; Fullmer et al., 2015). Compher and colleagues (2006) suggest in their review probability of error when RQ is <0.70 and >1.

In exercise physiology, the term respiratory exchange ratio (RER) is more commonly used, as RQ is measureed through invasive procedures and thus is more demanding.

RER is also an estimate on VCO_2/VO_2, however, in contrast to RQ measured directly in the cells, RER measures the gas exchange in the lungs through inhaled and exhaled air (McArdle, Katch & Katch, 2015). This can be done through IC. During rest and steady state it is established that RER accurately reflects what happens at the cellular level (McArdle, Katch & Katch, 2015).

It is widely suggested in the literature that the first 5 minutes of measurement should be discarded to exclude any potential dead volume in the equipment (Compher et al., 2006; Fullmer et al., 2015). Steady state (SS) is commonly used in calculation of RMR and can be defined as a minimum variation in gas exchange in a specified time period (Compher et al., 2006; Fullmer et al., 2015). When measuring RMR, a coefficient of variation <10% for VO2 and VCO2 is commonly used to determine an accurate measurement (Compher et al., 2006; Fullmer et al., 2015). When 5 min of SS is obtained, RMR values is adequate to estimate an individual's resting energy expenditure during a 24h period (Branson & Johannigman, 2004; Compher et al., 2006). Through Weir´s equation (Weir, 1949), measured VO_2 and VCO_2 from the IC are converted to resting energy expenditure as kcal/day.

Weir´s equation (Weir, 1949): kcal/day = 3.94 (VO2) + 1.1 (VCO2) x 1.44

2.3.2.1 Measurement conditions

In contrast to BMR, RMR is measured without the subject having stayed at the laboratory over night. Hence, a rest period is crucial for the metabolic rate to return to resting levels before the measurement is conducted (Fullmer et al., 2015). Fullmer et al. (2015) suggest the subject to get to the laboratory by passive transportation with a rest period of 20-30 min in advance of the measurement. Compher and colleagues (2006) suggest on the other hand in their systematic review, that 10 to 20 minutes rest is adequate to achieve accurate RMR values in healthy individuals. A minimum of 5-7 hours fasting should be required prior to the RMR measurement to ensure an elevated RMR due to a meal is returned to normal levels (Compher et al., 2006; Fullmer et al., 2015). Sufficient evidence regarding minimum absence from physical activity prior to RMR measurement is limited as the recovery time varies between different type of PA/exercise, duration and intensity (Compher et al., 2006). However, a minimum of 2 hours after moderate physical activity and up to14 hours after vigorous exercise is suggested (Compher et al., 2006).

2.3.3 How to predict RMR

There are some limitations regarding RMR measurement in a laboratory. Direct and indirect measurement of RMR are both time consuming, requires specialized equipment and sets some requirements for participants in advance regarding physical activity, food intake, rest etc (Compher et al., 2006). Thus, simple methods for estimating RMR have emerged. Based on evidence saying that heat production is highly correlated with stature, body weight, age and gender, Harris & Benedict (Haris & Benedict, 1918) developed an equation that predicts resting metabolic rate based on these factors. Several different equations for estimating RMR have been developed over the years. The different equations are based on divergent populations, regarding age, sex and BMI (table 1). Harris-Benedict, WHO and Mifflin are suggested some of the most used equations to predict RMR (Psota & Chen, 2013) and are presented in Table 1.

Flack and colleagues (2016) did a cross-validation study on 8 different RMR prediction equations where predicted RMR was tested for agreement against indirect calorimetry. The study was done on healthy nonobese and obese adults and the results showed that Harris-Benedict (Harris & Benedict, 1918) and WHO (WHO, 1985) equations were the only equations that did not differ from measured RMR. These equations were seen as the most accurate predictions at group level. However, at individual level all of the equations became less accurate with increasing FFM, with 76.7% and 66.7% accuracy for Harris-Benedict and WHO (Flack et al., 2016). Using prediction equations to estimate RMR should therefore be used with caution on individual levels. Weijs and Vansant (2010) did a similar validation study in which they tested 27 predictive equations against indirect calorimetry. The results showed that Harris-Benedict (Harris & Benedict, 1918) and Mifflin (Mifflin et al., 1990), two commonly used equations in clinical practice provide 69% and 68% accurate predictions on RMR across a variety of body weight and BMI (Weijs & Vansant, 2010). The established equations have been criticized due to impaired accuracy in obese individuals, however, in nonobese populations, Harris-Benedict and Miffin equations seem to be more accurate (Frankenfield et al., 2003).

Table 1: Three commonly used resting metabolic rate prediction equations. All tested for agreement towards indirect calorimetry in different studies. BMI, body mass index: y, age in years: RMR, resting metabolic rate: IC, indirect calorimetry.

Method	Developed	Population	Equation to predict RMR	Accuracy towards IC
Harris-Benedict (Harris & Benedict, 1918)	1918	n= 239 (136 men, 103 women) **Mean age:** Men: 27 y Women: 32 y **Mean BMI:** Men: 21.4 Women: 24.4	Women: *655.10 + 9.56 x weight (kg) + 1.85 x height (cm) – 4.68 x age* Men: *66.43 + 13.75 x weight (kg) + 5.00 x height (cm) – 6.76 x age*	Flack et al., 2016: **76.7%** Weijs & Vansant, 2010: **69.0%** Frankenfield et al., 2003: **69.0%**
WHO (WHO, 1985)	1981	Based on data of 7000 subjects from >114 studies (67% men, 33% Women)	Women: 18-30yrs: *14.7 x weight (kg) + 496* 30-60yrs: *8.7 x weight (kg) + 829* Men: 18-30yrs: *15.3 x weight (kg) + 679* 30-60yrs: *11.6 x weight (kg) + 879*	Flack et al., 2016: **66.7%** Weijs & Vansant, 2010: **60.0%**
Mifflin (Mifflin et al., 1990)	1990	n= 498 (251 men, 247 women) **Mean age:** Men: 44 y Women: 44 y **Mean BMI:** Men: 27.5 Women: 26.2	*9.99 x weight + 6.25 x height – 4.92 x age + 166 x sex (men: 1, women: 0) - 161*	Flack et al., 2016: **73.4%** Weijs & Vansant, 2010: **68.0%** Frankenfield et al., 2003: **82.0%**

2.4 Criteria for clinical low RMR

Measured RMR (mRMR) is often compared with predicted RMR (pRMR), in which Harris-Benedict equation (Harris & Benedict, 1918) is commonly used, to interpret whether the metabolic state is hypermetabolic, normometabolic or hypometabolic (Schebendach, 2003). A hypermetabolic state is according to McArthur (as cited in Schebendach, 2003) when mRMR is 10% higher than pRMR. Normometabolic state is when mRMR is within 10% of the predicted RMR while a hypometabolic state is defined when mRMR is 10% lower than pRMR (Schebendach, 2003). The ratio between mRMR and pRMR is often used to determine metabolic state and is calculated as mRMR/pRMR (Staal et al., 2018). A hypometabolic state or a suppressed RMRratio is defined as RMRratio <0.90 and this cut point for hypometabolism is widely used in the literature (De Souza et al., 2008; Melin et al., 2015; Schebendach, 2003; Staal et al., 2018; Vescovi et al., 2008).

2.5 Physical activity and RMR

It is established that change in body composition, especially FFM may lead to an increase or decrease in RMR (McArdle, Katch & Katch, 2015). Physical activity and exercise is an important contributor to change body composition (McArdle, Katch & Katch, 2015). Physical activity is one of the core elements in the modern fitness lifestyle (Helms, Aragon & Fitschen, 2014b; Lambert, Frank & Evans, 2004), with main focus on resistance training. Aristizabal and colleagues (2015) examined the effect of resistance training on RMR in 61 healthy recreationally active men and women who were in energy balance. The participants conducted a whole-body training program three times a week for 9 months. A significant increase in RMR of 5% (73 ±158 kcal/day, p<.01) was seen by the end of the intervention. The authors explain the raise in RMR mainly by an increase in FFM. Similar results were detected by Kirk et al. (2009) with 7% increase in RMR (162 ±41, p<.001) after 6 months of full-body resistance exercise, three times per week, in 63 overweight young men and women. The participants obtained their normal ab-libitum diet throughout the study. Increased FFM was assumed to be an important contributor, however, RMR was also increased due to resistance training even when adjusted for FFM. Thus other unknown factors must participate to the increased RMR following exercise.

Woods and colleagues (2018) examined, among other things, the effect of an intensified training period in elite male cyclist on RMR. The result showed a significantly decrease (p<.001) in RMR after a period of 2 weeks with 150% of regular training load. After 2 weeks recovery (80% of regular training load), RMR values were back to baseline levels. In contrast to the research done by Aristizabal et al (2015) and Kirk et al (2009), Woods et al (2018) examined the effect of endurance- and not resistance training. The opposite effect may therefore be due to lower energy availability as a result of greater energy expenditure during aerobic exercise compared to resistance training.

According to McArdle and colleagues (2015) physical activity may also impact other factors related to RMR. A study done by Poehlman & Danforth (1991) showed a 10% increase (144 kcal/day) in RMR after 8 weeks of aerobic training in older individuals, despite no change in fat free mass. The authors suggest that high-energy flux may increase RMR in older adults independent of FFM. A study done on 13 healthy men aged 50-65 years old, showed an 8% increase in RMR when they increased their FFM due to 16 weeks of maximal resistance training, with three full-body work outs every week (Praterly et al., 1994). McArdle et al., (2015) suggest that both resistance and endurance training may prevent decrease in RMR due to aging, and that PA also has additional effects on RMR, not only FFM.

2.6 Body composition and RMR

The main focus during preparation for a fitness contest is to change body composition, aiming to reduce fat mass while maintaining muscle mass. Body fat can distinguish between essential- and storage fat, whereas essential fat is the fat within the bone marrow, nerve tissue and organs, while storage fat is mainly subcutaneous- and visceral adipose tissue (McArdle, Katch & Katch, 2015). Essential fat is required to obtain physiological vital function, and accounts for 12 % of body mass in women (McArdle, Katch & Katch, 2015). Thus, %BF of 12 is suggested to be the absolute minimum in terms of maintaining optimal health (McArdle, Katch & Katch, 2015; Meyer et al., 2013). Storage fat is suggested to account for ≥15 % of total body mass (McArdle, Katch & Katch, 2015).

According to McArdle and colleagues (2015), average %BF in female bodybuilders is 13.2%. However, this is based on a small sample size of only 10 competitive female bodybuilders. A study done by Van der Ploeg et al. (2001) showed an average %BF in five female bodybuilders of 13.6% and 9.7%, 6weeks and 3-5 days before competition. Hulmi et al. (2016) reported mean %BF of 12.7 in 27 female fitness athletes the morning after a fitness competition. Meyer and colleagues (2013) suggest %BF between 12-14 to be the lower limit in females to prevent negative health consequences.

Inter-individual variation in RMR is mainly explained by FFM, and FFM is seen to be the single best predictor for RMR (Kenney, Wilmore & Costill, 2015). However, FFM only accounts for 60-85% of RMR, and the remaining 15-40% variation in RMR is left unexplained (Nielsen et al., 2000). Question has been raised regarding body fat as an independent predictor for RMR, due to oxygen consumption in adipose tissue. However, there are different findings in the literature, where some research indicate that FM is an independent predictor for RMR, while others do not (Cunningham, 1991; Dionne et al., 1999; Herbert et al., 2001; Nielsen et al., 2000). Characteristics and results from existing literature regarding RMR and body composition are presented in table 2.

Nielsen and colleagues (2000) examined the role of fat mass (FM) and FFM on RMR in 253 healthy men and women. The results showed a significant correlation (p<.001) between RMR and FM (r=.63) as well as RMR and FFM (r=.65) in women. Same results was seen in men, with r=.48 and r=.62, respectively. A moderate correlation was seen between RMR and %BF, with r=.55 and p<.001. According to the findings in Nielsen et al (2000), 22% of the variation in RMR in women, and 11% in men may be explained by FM (r^2=.22, p<.0001, r^r=.11, p<.0001). Same results was found regarding FFM (r^2=.21, p<.0001). Dionne and colleagues (1999) found similar results showing that FM accounts for 20% (p<.0001) of the variation in RMR in women, and 31% (p<.0001) for men. FFM was however a bigger predictor to RMR in this study compared to what was found by Nielsen et al (2000), with r^2=.50 (p<.0001). In contrast, Herbert and colleagues (2001) found that only 2-3% of variation in RMR can be explained by FM (p<.001). FFM however, accounts for 44% and 54% of inter-individual variation in RMR in women and men respectively. Cunningham (1991) did not find FM to be an independent predictor for RMR for the general population in his review. Yet, he points out the possibility of FM as a potential predictor in obese women.

Table 2: Characteristics and results from existing literature regarding RMR and body composition. Values presented as mean and SD.

Study	Population	BMI kg/h^2	RMR (kcal/day)	FFM (kg)	Correlation	R^2	FM (kg) / %BF		Correlation		R^2	
Dionne et al., (1999)							**FM:**		**FM:**		**FM:**	
	Women: n=35	29 ± 8	1904 ± 282	47 ± 7	$.82^{**}$	$.50^{***}$	29 ± 18		$.44^{*}$		$.20^{***}$	
	Men: n=65	29 ± 6	2332 ± 456	65 ± 11	$.58^{**}$	$.35^{***}$	24 ± 15		$.71^{**}$		$.31^{***}$	
Nielsen et al., (2000)							**FM:**	**%BF**	**FM:**	**%BF**	**FM:**	**%BF**
	Women: n=153	24 ± 8	1494 ± 223	43 ± 6	$.65^{**}$	$.21^{***}$	24 ± 16	36% ± 12	$.63^{**}$	$.55^{**}$	$.22^{***}$	-
	Men: n=100	25 ± 5	1887 ± 243	64 ± 10	$.62^{**}$	$.29^{***}$	16 ± 12	21% ± 10	$.48^{**}$	$.38^{**}$	$.11^{**}$	-
Herbert & Neuh., (2001)							**FM:**	**%BF**	**FM**	**%BF**	**FM**	**%BF**
	Women: n=164	26 ± 4	1314 ± 155	37 ± 5	$.73^{**}$	$.54^{**}$	30 ± 6	44% ± 4	$.63^{**}$	$.21^{*}$	$.03^{**}$	-
	Men: n=98	26 ± 3	1620 ± 178	53 ± 5	$.66^{**}$	$.44^{**}$	25 ± 5	32% ± 4	$.47^{**}$	.16	$.02^{**}$	-

%BF percentage of body fat, FM Fat mass (kg), FFM Fat-fre mass (kg), RMR Resting metabolic rate

* p <.05

** p< .001 <.**0001**

2.7 Weight loss and RMR

2.7.1 Calorie deficit and RMR

Calorie deficit is crucial to lose weight (Martin et al., 2007). During preparation for a fitness competition energy deficit is mainly detrived by reduced energy intake along with increased levels of PA (Helms et al., 2014b). Energy deficit leads to a variety of biological responses. It is established that calorie deficit will slow down metabolism, due to metabolic adaption (Melby et al., 2017). The human body will always strive for homeostasis and thus adapt to the current condition to survive. When in negative energy balance, a state of nutrient deprivation is communicated to the brain and the body puts itself in starvation mode (Melby et al., 2017). One of these adaptions is to slow down metabolism (Melby et al., 2017). Leptin, triiodothyronine, insulin, and other peptides involved in energy homeostasis, are suggested to be some of the metabolic adaptions to energy restriction and are associated with altered RMR during weight loss (Koehler et al., 2016). Due to the inter-individual difference in RMR, the complete cause and the exact mechanisms of RMR suppression in response to energy deficiency remains unclear (Aristizabal et al., 2015; Kenney, Wilmore & Costill, 2015; Koehler et al., 2016).

Research on calorie deficit and its effect on RMR suggest that the addition of exercise is preferable in terms of maintaining normal RMR (Stiegler & Cunliffe, 2006). Martin and colleagues (2007) examined the effect of calori deficit due to 25% calori restriction (CR) or combined CR and exercise (12.5% CR and 12.5 increased exercise energy expenditure) on resting metabilic rate. The results showed that the CR group had a significant decrease ($p<.01$) in RMR after 3 months, while decrease in RMR did not occur in the CR+EX group before 6 months, suggesting that structured exercise may slow down the declination rate of RMR during weight loss. When a very low calorie diet (800kcal/day) was combined with either aerobic exercise (AE) or resistance training (RE), Bryner et al (1999) found that there was a significant reduction in RMR (-211 kcal/day, $p<.05$) only in the diet + AE group. No significant reduction in RMR was found in the diet + RE group. The difference seen in RMR between D+AE and D+RT group, can be due to increased energy expenditure in D+AE and greater loss of FFM compared to what seen in D+RT group.

2.7.2 RMR after weight loss

Decrease in RMR following weight loss is well established (Martin et al., 2007; Stiegler & Cunliffe, 2006). A meta-analysis provided by Alstrup and colleagues (1999) showed 3-5% lower RMR in obese subjects who had lost weight compared with controls without any weight loss. Melby et al (1989) found that wrestlers had 16% lower RMR during the season compared to preseason levels. Similar result has been seen in nonobese and obese individuals (Body-Westphal et al., 2013; Fothergill et al., 2016; Kajioka et al., 2002). In contrast, Sagayama and colleagues (2014) did not detect any change in RMR following rapid weight loss in weight-classified athletes.

According to McArdle and his colleagues (2015) RMR is the biggest contributor to TDEE with 60-75% of the contribution. Thus, attenuating the decrease in RMR during weight loss (WL) may have a great impact on weight maintenance and to decrease eventual weight regain (Melby, Paris & Peth, 2017). High-energy flux is a state where an individual maintain energy balance, due to high levels of energy expenditure from exercise and training, accompanied by high daily energy intake (Melby, Paris & Peth, 2017). Research done on young females, males and older adults (Bell et al., 2004) showed that high-energy flux is associated with higher levels of RMR. Maintaining exercise and high PA-levels may therefore be crucial to RMR levels after weight loss (Melby, Paris & Peth, 2017).

2.7.3 RMR in rapid vs slow weight loss

Weight loss within a specified period of time is essential before a fitness competition. The goal is to get rid of a great proportion of fat while maintain muscle mass. Greater energy deficits yield faster weight loss, however, this seems to result in a bigger proportion of weight loss achieved by FFM (Helms et al., 2014b). Garthe et al. (2011) found slow weight loss (0.7% of BW/week) to be more beneficial to FFM compared to rapid weight loss (1.4% of BW/week) in athletes. As we do know that FFM is the biggest contributor to RMR, slow weight loss might therefore be more beneficial to maintain RMR during weight loss (Helms et al., 2014b). This is supported by Ashtary-Larky and colleagues (2017) who examined the effect of rapid vs slow weight loss on RMR in 42 overweight and obese individuals. The result showed that those who lost 5% of BW within 5 weeks had a significant greater increase ($p<.001$) in RMR compared to those who lost 5% of BW within 15 weeks (-59.3 kcal/day vs. -22.9 kcal/day). This suggest that slow weight loss may be beneficial in terms of maintain RMR or decrease the rate of RMR reduction during weight loss.

2.7.4 RMR after weight regain

Weight regain is a common phenomenon after weight loss, and it is estimated that only 20% of those achieveing significant weight loss success in weight maintainance (Melby et al., 2017). RMR appears to be an important contributor to weight maintenance (Melby et al., 2017), and thus, it is interesting wheter or not RMR return to pre-weight loss values when lost weight is regained. The literature shows various outcomes regarding RMR after weight regain. Fothergill and colleagues (2016) examined long-term changes in RMR in 14 obese individuals that had participated in the TV show "The Biggest Looser", and found that despite substantial weight regain six years after the participation; RMR remained suppressed at the same levels as after the weight loss. Similar result was found in a study done by Bosy-Westphal and colleagues (2013) which showed a sustained RMR reduction in overweight and obese individuals who regained weight 6 months after weight loss, compared with those who managed to maintain their weight loss, who recovered their expected RMR. A study done on non-obese young women who lost and regained weight during a period of 44 days, with a subsequent weight loss during the next 30 days showed a significant decrease in RMR at day 74, the end of the intervention (Kajioka et al., 2002). They also found a sustained and significant decrease in RMR 106 days post intervention, although body weight was back to baseline values.

Sagayama and colleagues (2014) examined body composition and energy expenditure after rapid weight loss (5% of body weight (BW) in 7 days) following weight regain within 12 hours in weight-classified athletes. The results showed no significant change in BMR throughout the study. Hulmi and colleagues (2016) examined body composition and hormonal changes during weight loss and weight regain in female fitness athletes. They reported a significant reduction in thriiodothyronine (T3) hormone after weight loss. After 3-4 months of recovery, T3 levels were still slightly significant below baseline levels. RMR was not measured; yet, low T3 levels are associated with decreased metabolic rate. A study done on 12 weight-cycling collegiate wrestlers where RMR was measured before, during and after a wrestling season found that RMR was significant reduced from baseline values during the 6 month wrestling season (Melby, Schmidt & Corrigan, 1989). Weight loss was mainly due to the combination of restricted diet and exercise, with acute dehydration techniques the last hours prior to weight-in (Melby et al., 1989). The RMR did however return back to baseline values as a result of post-season weight regain. The literature shows various outcomes regarding RMR after weight regain. However, RMR seems to adapt better to weight regain in athletes or well-trained individuals compared to overweight and obese individuals. This is supported by Molé and colleagues (1989) who suggests that daily exercise offset the decline in RMR during severe calorie restriction.

Table 3: Characteristics and results from existing literature regarding RMR and weight regain. Values presented as mean and SD.

Study	Sample	% BF baseline	BW baseline (kg)	BW WL (kg)	BW WR (kg)	RMR baseline (kcal/day)	RMR WL (kcal/day)	RMR WR (kcal/day)
Fothergill et al., (2016)	14 obese individuals that participated in the TV show "The Biggest Looser"	49% ± 5	149 ± 41	91 ± 25*	132 ± 45$^{\#a}$	2607 ± 649	1996 ± 358*	1903 ± 466^{a}
Bosy-Westphal et al., (2013)	27 obese men (n=6) and women (n=21). Mean age (y): 37 ± 6	44% ± 7	106 ± 20	-9 ± 4	+6 ± 2	1870 ± 328	-160 ± 152*	+55 ± 158^{a}
Kajioka et al., (2002)	5 healthy nonobese women. Mean age: 25 ± 5	24% ± 2	52 ± 2	48 ± 2	52 ± 2	-	-*	-^{a}
Sagayama et al., (2014)	10 healthy japanese male weight classified athletes Mean age: 20 ± 1	17 % ± 7	74 ± 9	70 ± 9 *	73 ± 9$^{*\#}$	1998 ± 242	1846 ± 261	1852 ± 245
Melby et al., (1989)	26 well-trained wresteler Mean age: 19 ± 1	10 % ± 1	71 ± 3	66 ± 2	73 ± 3	1973 ± 64	1644 ± 63*	2030 ± 91$^{\#}$

%BF, percentage of body fat; BW, Body weight; RMR, resting metabolic rate; WL, Weight loss; WR, Weight regain; BW WL, Body weight after weight loss; BW WR, Body weight after weight regain.

* p<.05 WL vs baseline, # p<.05 WR vs weight loss, a p<.05 WR vs baseline

Exercise and healthy food are core elements in the lifestyle of fitness athletes and they emphasize the value of staying lean, muscular and defined (Halvorsen, 2015). In a world facing a global epidemic of obesity; physical activity and healthy diets are encouraged both by the government and health professionals (Helsedirektoratet, 2014a; Helsedirektoratet, 2014b). Due to the lack of evidence concerning health in fitness athletes, professionals have remained silent in public debates as it´s difficult to counteract apparently healthy action such as increased physical activity and healthy diet. Previous research regarding low energy availability due to prolonged restrictive diets to be associated with low %BF and FFM, along with decreased bone mineral density and other changes with negative health consequences (Sundgot-Borgen et al., 2013). Calorie deficit, combined with decreased %BF and especially low amounts of visceral adipose tissue are among other tings thought to reduce secretion of hormones relating to ovulation and menstrual bleeding (Hulmi et al., 2016). This may have detrimental consequenses in females. Thus, this research is important to improve knowledge about the health effects of the modern fitness lifestyle and whether there is a need to establish evidence based guidelines for fitness athletes´ exercise and competition preparation.

3.0 Materials and Methods

3.1 Study design

This master thesis is part of a larger research project named “Fitness Health”, a prospective cohort study examining the effect of a fitness lifestyle, including fitness contest preparation on selected aspects of both psychological- and physical health in female fitness athletes. Outcomes was compared to a recruited, physically active, age matched, female population. The participants had to meet at the Norwegian School of Sports Sciences (NSSS) for screening at three times during the study. The physical and psychological screening consisted of a dual x-ray absorptiometry (DXA) scan, RMR-measure through indirect calorimetry, a selection of validated questionnaires and 4 days diet registration. Only RMR-measures are further described in this thesis. The first screening took place one-mont before their contest diet was initiated, 3-4 months pre-contest (figure 1). The participants followed a self-prescribed diet, and did not receive any dietary consultation as a part of this study protocol. Two weeks prior to their first seasonal competition the physical and psychological screening was repeated. The last measurement was arranged one month after their last competition appearance. The participants in the control group were following the same procedures and were tested at the same time as the fitness athletes.

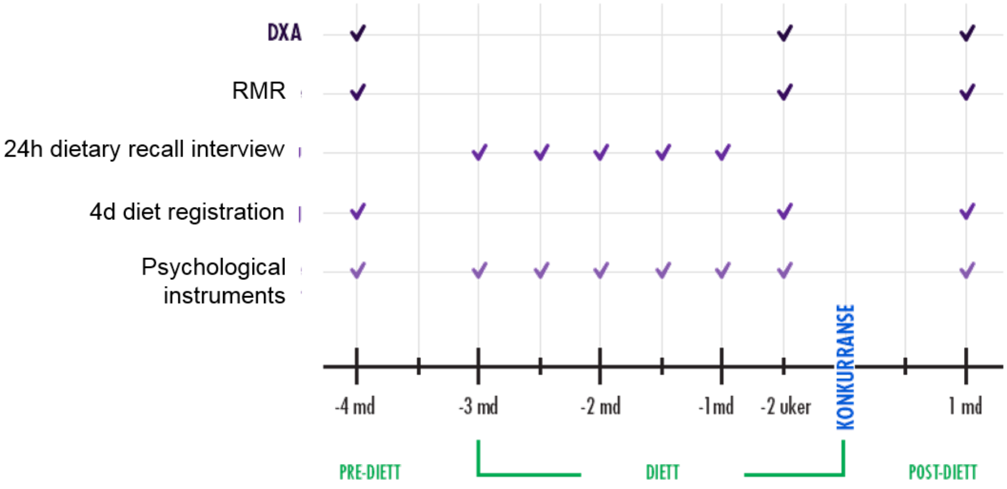

Figure 1: Outline of the study design. Fitness athletes and physically active controls were screened on selected aspect of psychological and physical health four months before the competition (equivalent to one-month before the preparatory diet starts). A questionnaire and recall interview on their diet was conducted every second week until two weeks before the competition. The entire test battery was repeated two weeks prior to the competition and one month after the last contest.

The aim of this master thesis is to detect any change in RMR before, during and after a fitness competition, and further description of the method will therefore only include measurements related to this outcome, i.e. RMR, height and weight.

3.2 Selection and recruitment

Competitive female fitness athletes aged 18-40 were recruited to this study, and observed during their 3-4 months preparation period prior to fitness contest during spring or autumn 2017, with a one-month follow-up. Age matched, recreational physically active females, corresponding to at least 2 sessions per week, not planning to take part in any contest, and with no history of fitness-sport or bodybuilding was recruited to participate as a control group. To be as comparable as possible to the fitness group, the participants in the control group had to have a body mass index (BMI) between 17.5 and 30 kg/m^2. Both the fitness athletes and the physically active controls performed the same physical and psychological screening and answered the same questionnaires and dietary assessment throughout the fitness preparation period. All were following their individual and preferred diet and exercise routines.

Physical active controls with previous experience from fitness or bodybuilding, personal trainers and those who wanted to participate in a fitness- or bodybuilding competition in the future were excluded from the study. Those who were not able to meet at the Norwegian School of Sport Sciences for baseline and follow up screenings were also excluded from the study and pregnant or nursing women or individuals with metabolic related diseases were not allowed to engage in the study.

The recruitment occurred during the autumn 2016 and spring 2017. Fitness athletes were recruited through the Norwegian National Federation for Bodybuilding & Fitness (NKF), their affiliated clubs, fitness team leaders and through social media. Physical active controls was recruited through gyms and training facilities in Oslo and surroundings, in addition to social media and colleagues at NSSS. A website was created to provide further information about the study, how to engage, as well as to present the aim and the background of the study. Through www.fitnesshelse.blogspot.no potential participants was encouraged to contact the project manager for further information and enrollment.

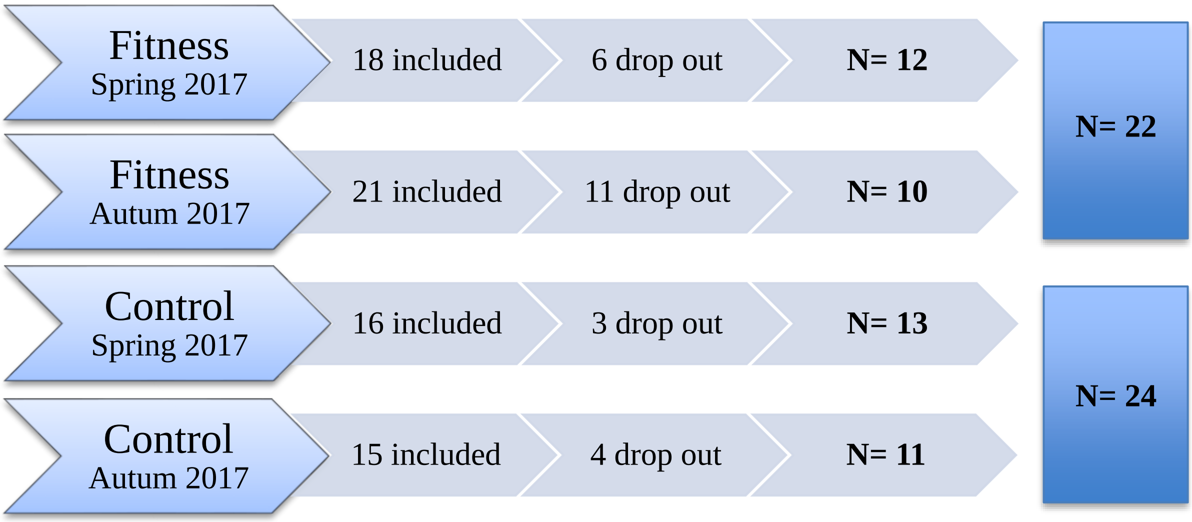

Figure 2: Outline on the inclusion- and exclusion process. Proportion of drop-out and finale sample of fitness athletes and PA controls.

3.2.2 Power calculations

It has not been performed any statistical power calculations in the present study. The number of participants is based on previous studies that address RMR (Flack et al., 2016; Reeves et al., 2004). Both Flack and colleagues (2016) and Reeves et al (2004) preformed statistical power calculations, which indicated that a sample size of 29 and 21, respectively, was adequate to achieve 90% power at 95% significant level. Thus, the desired number of participants in this study was to recruit 60 participants in total, of which 30 fitness athletes and 30 controls.

3.2.3 Information given to the participants

Those who responded to recruitment got an oral orientation over telephone about the aim and implementation of the study. Those with further interest received electronic written information by e-mail, which gave a detailed introduction about the background of the study as well as the study design. The potential participants also received an informed consent by mail, which they had to sign to take part in the study.

3.3 Measurement

3.3.1 Anthropometric measurements

Anthropometric measures were conducted as part of the RMR measurement. An electronically weight scale and a fixed stadiometer (Seca, Hamburg, Germany, Mod: 8777021094, S/N: 5877217129382) was used to measure weight and height of the participants. All measurements were done without shoes and in light clothing. For the weight measure the participants were asked to stand in a straight position with arms down, on the middle of the weight plate and look straightforward. The weight was measured to the nearest 0,1 kg. Each participant was then asked to stand with both heels touching the back of the stadiometer to measure their height. They were asked to stand in a straight position and to stretch the spine, with the chin slightly turned upwards (ISAK, 2001). The height was measured to the nearest 0,1 cm.

Figure 3: Body position during weight measurement. A straight body position with arms down, standing on the middle of the weight plate looking straightforward.

Figure 4: Body position during height measurement. A straight position with a stretched spine, and with the chin slightly turned upwards.

3.3.2 Resting metabolic rate

Resting metabolic rate was measured using indirect calorimetry at the Norwegian School of Sports Sciences (NSSS). RMR was measured by a respiratory gas analyzer (Oxycon Pro, Jaeger, Tyskland), using the “breath by breath” technique. According to the recommendations stated in the Oxygen Pro, Jaeger, Germany user manual, the analyzer was gas- and volume calibrated each morning prior to the measurements. Ambient conditions were also registered. The participants were asked to meet in a fasting state, without any solid foods or liquids eight hours in advance of the test. No intensive physical activity was allowed the last twelve hours before testing and the participants were asked to arrive by passive transportation. All RMR measurements were conducted between 7.30 AM and 11 AM. Patient data such as height, weight, age, sex and ID-number was filled into the software. The RMR test was conducted in a room with soft lighting, on a mattress in supine position, with the head resting on a pillow and covered by a blanket. Each participant received an individual customed two-way breathing mask (2700 series; Hans Rudolph, Inc.), which was placed over the nose and mouth and connected to a valve (Hans Rudolph Douglas valve, Hans Rudolph Inc., Kansas City, USA).

The test started with a resting period of 10 minutes where the participant was laying on a mattress in a supine position. A spO2 (Welch Allyn Spot Vital Signs LXI Monitor with SureBP, Nellcor Sp02) was attached on the tip of a finger to detect resting heart rate (HR). HR was measured after 10 minutes or as the lowest HR registered. After 10 minutes the test personnel connected the gas analyzer to the mask and the gas exchange and ventilator variables was measured continuously for 20 minutes, or until stable gas exchange values was achieved (defined as less than 10% variation in VO_2 and VCO_2). Resting metabolic rate was calculated with Weir equation: kcal/day = 3.94 (VO2) + 1.1 (VCO2) x 1.44 (Weir, 1949).

Table 4: Time schedule for measurement of resting metabolic rate.

Duration	**Activity**
10 min	Attendance (fasting) + anthropometric measurements, patient data registration and mask customization.
10 min	Resting on a mattress in supine position.
20 min	Continuous measurement of RMR

Figure 5: Body position during indirect calorimetry. Supine body position on a mattress, with a spO2 attached to the tip of a finger and a 2700 series; Hans Rudolph individual custom mask over the nose and mouth connected to a Hans Rudolph Douglas valve.

3.5 Reliability and validity

Indirect calorimetry (IC) is the most used method to measure energy expenditure and remains the gold standard in clinical settings (Haugen, Chan & Li, 2007). To ensure the conditions were standardized, the equipment was calibrated every day before testing. Even though the same person did not perform the test every time, all the test personnel had to undergo the same training and certification to make sure they followed the same procedures.

Douglas Bag is established as the gold standard of the IC devices (Haugen, Chan & Li, 2007). In the present study resting metabolic rate was measured using Oxycon Pro gas analyzer. Oxycon Pro has been tested against Douglas Bag to detect validity (Carter & Jeukendrup, 2002; Rietjens et al., 2001). Both Carter & Jeukendrup (2002) and Rietjens et al (2001) found that Oxygen Pro is a valid and accurate device to measure energy expenditure both in rest and during activity.

3.6 Data treatment and statistical analysis

IBM SPSS statistics version 24 was used to perform all statistical analysis in the present study, while tables and figures were constructed in Microsoft Excel for mac 2011, version 14.7.7. Raw data material was plotted into an excel file before the data set was transferred into SPSS. The output from indirect calorimetry was plotted into a pre-developed calculation sheet to compute RMR for each individual. First 5 minutes of measurement was rejected and the lowest measured VO_2 and CVO_2 with coefficient of variation <10% was used to determine each individuals RMR.

All variables were tested for normality through Shapiro-Wilk test of normality, as well as interpretation of histogram and Q-Q plot. All variables were assumed and treated as normal distributed in the statistical analysis and thus parametric tests were used. The level of significance was set to $\alpha < 0.05$, meaning that a p value less than 0.05 were defined as statistical significant (O'Donoghue, 2012).

The descriptive data are presented as mean and standard deviation for both fitness athletes and physical active controls. A one-way repeated measure ANOVA was performed to assess the change in mean RMR between the three screening points. Cohen´s (1988) interpretation of effect size (.01 = small, .06 = moderate, .14 = large effect) was used to interpret the effect size (partial eta squere) of the one-way repeated measure ANOVA analysis. A pairwise comparison, bonferroni post hoc test, was conducted to detect which of the measurement points differed from each other.

Hypometabolism was calculated through the ratio between mRMR (IC) and pRMR (HarrisBenedict). Any ratio below <0.9 was defined as suppressed RMR (De Souza et al., 2008; Melin et al., 2015; Schebendach, 2003; Staal et al., 2018; Vescovi et al., 2008). The change in proportion of fitness athletes and PA controls classified as hypometabolic at the three screening point was tested using Cochran´s Q-test for repeated measures in nominal data. When Cochran´s Q test showed a significant difference (p<.05), McNemar post-hoc test was performed to detect changes within the three different measure points. To interpret the results from McNemar post-hoc test, a bonferroni adjustment was conducted and the significance level (p<.05) was devided on three (due to three pairwise comparison). p<.016 was the new significance level used to interpret the results from McNemar post-hoc test.

Pearson´s correlation was completed to examine the association between RMR-ratio and %BF, RMR-ratio and weight change, RMR-ratio and percentage change in %BF. Percentage changes were calculated from the following formula: ((New value (post) – original value (pre)) / Original value (pre)) * 100. A correlation coefficient below 0.2 was interpreted as no correlation, 0.2-0.45 was considered a weak correlation, 0.45-0.7 as moderate correlation while values > 0.7 was seen as a strong correlation (O'Donoghue, 2012). Simple linear regression analysis was performed to predict the relationship between the current variables.

3.7 Ethics

As already mentioned the present study is part of a larger research project named ”Fitness Health”, a study focusing on the health of competitive female fitness athletes. “Fitness Health” was approved by regional committees for medical and health research ethics 28th of March 2017 (appendix 1). This project do also meet the terms and condition of the declaration of Helsinki as well as the law for health research and the study is registered in the Protocol Registration and Result System; Clinical Trials (ID: NCT03007459, appendix 2). All participants had to sign an informed consent (appendix 3) to confirm that they would like to participate in the study and approve that their test results are being used anonymously in the publication of the study. The informed consent consisted of information regarding the aim of the study, the study protocol, confidential storage of personal data, and the fact that the participants under any circumstances and at any point are allowed to withdraw from the study without giving any reason.

Each participant got an ID-number, which was connected to name and personal data. Only the project manager had access to this connection. All the project assistants were subject to confidentiality, and all information was treated confidentially. The research project is founded by NSSS in collaboration with the National Dairy Council and there are no conflicts of interest.

4.0 Results

4.1 Descriptive data

A total of 70 participants, of which 39 fitness athletes and 31 physically active controls were included in the present study. A final sample of 46 participants, n=22 Fitness athletes and n=24 physically active controls were included in the statistical analysis, all which had completed RMR-measurement at all three screening points. Reason for drop-out among fitness athletes were reported to be due to illness/injury (n=2), lack of desired physique (n=4), deaths within the family (n=2), lack of motivation (n=1), family circumstances (n=3) and logistics/work (n=1). One of the athletes reported that she resigned from the competition due to development of unhealthy body image and mental challenges as a result of the pre-contest preparations. 3 participants were unwilling to respond. Reasons for drop-out in PA controls were reported to be due to family circumstances (n=1), illness or injury (n=2), logistical challenges (n=2) and aversion to respond (n=3). Out of the 22 fitness athletes, 18 competed in bikinifitness, 3 in body fitness and 1 in athletic fitness. Descriptive data are presented in Table 5 as mean and standard deviation**.** There was no statistical difference between the fitness athletes and the physically active controls at baseline (table 5). The fitness athletes' former competition experience ranged from 0 to 9 competition appearances. More than half of the fitness athletes (63.6 %) had no competition experience at all before they engaged in this study.

Table 5: Descriptive data stated in mean and standard deviation (SD) for fitness athletes and physical active controls at baseline screening. Competition experience is presented as median and min-max values, due to skewed data.

	Fitness (n=22)		**Control (n=24)**		**P-value**
	Mean (SD)	**95% CI**	**Mean (SD)**	**95% CI**	
Age (year)	27.7 (±5.7)	25 – 30	29.4 (±6.0)	27-32	.354
Height (cm)	166.5 (±4.8)	164.3-168.6	166.8 (±5.2)	164.6-168.6	.837
Weight (kg)	62.5 (±7.1)	59.3-65.6	65.0 (±8.3)	61.4-68.4	.288
BMI (kg/m^2)	22.5 (±2.1)	21.6-23.5	23.4 (±2.9)	22.1-24.6	.272
Body fat (%)	25.0 (±5.9)	22.3-27.6	28.6 (±6.1)	26.0-31.2	.046
RMR (kcal/day)	1447 (±233)	1344-1551	1411 (±264)	1300-1523	.628
Experience (n)	0 (0-9)	-	-	-	-

4.2 Resting metabolic rate

The means and standard deviations for RMR before, during and after fitness contest are presented in figure 6. There was a significant effect for time, Wilks´Lambda = .40, F (2, 20) = 14.87, p < .001, multivariate partial eta squared = 0.60. Bonferroni post hoc test indicated a significant decrease (p=.002) in mean RMR (-184 ±46 kcal/day) from baseline to 2 weeks pre contest and a significant increase (p=.001) in mean RMR (326 ±74 kcal/day) from 2 weeks pre contest to one-month post contest. There was no significant difference in mean RMR one-month post competition compared to baseline (p=.294).

No significant effect over time in mean RMR was found in PA controls, Wilks´Lambda = .85, F (2, 22) = 1.90, p = .174, multivariate partial eta squared = .15. Bonferroni post hoc test showed no significant difference in RMR between the three different screening points in PA controls, (p=1.00, p=.455 and p=.449).

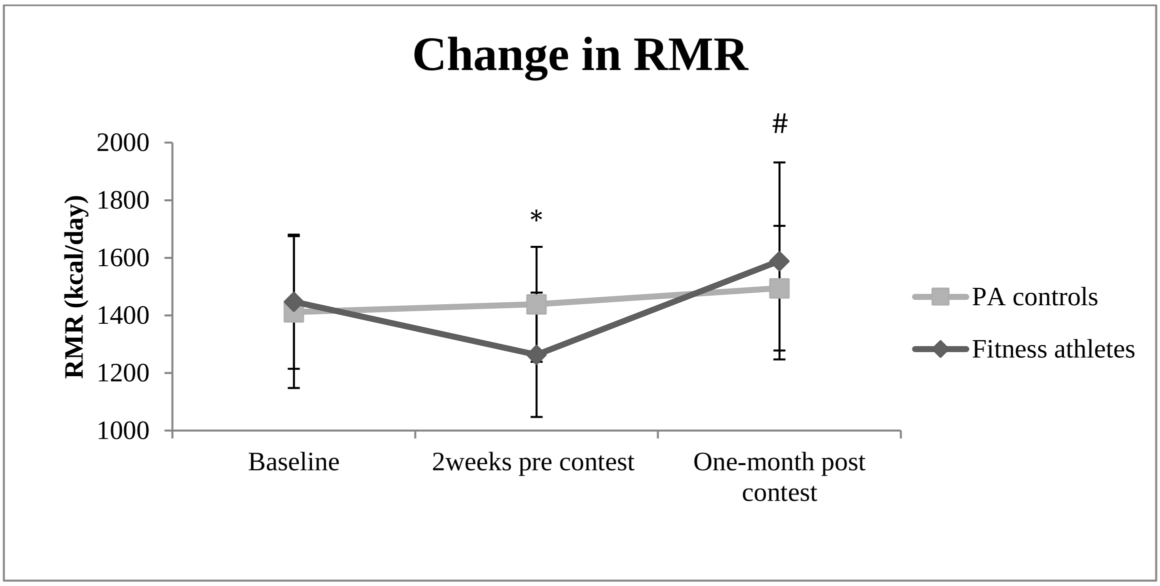

Figure 6: Resting metabolic rate (mean and SD) at the three different screening points; before diet, two weeks prior to competition and one-month post competition in fitness athletes and PA controls.

* Significant increse (p<.05) in RMR in Fitness athletes from baseline to two weeks pre contest.

Significant decrease (p<.05) in RMR in Fitness athletes from 2 weeks pre contest to one-month post contest.

4.2.1 Hypo metabolism

Figure 7 illustrates the proportion of fitness athletes and PA controls meeting the criteria for hypo metabolism. At the time of the second screening 13 out of 22 fitness athletes were hypo metabolic. This was a significant increase (p=.012) from baseline where only 4 of the 22 athletes had suppressed RMR. One-month post contest the proportion of fitness athletes classified as hypo metabolic was significantly decreased compared to two weeks pre contest (p=.003). No statistical difference was seen between baseline and one-month post contest (p=.668). There was no significant change over time regarding hypo metabolism in PA controls (p=0.368).

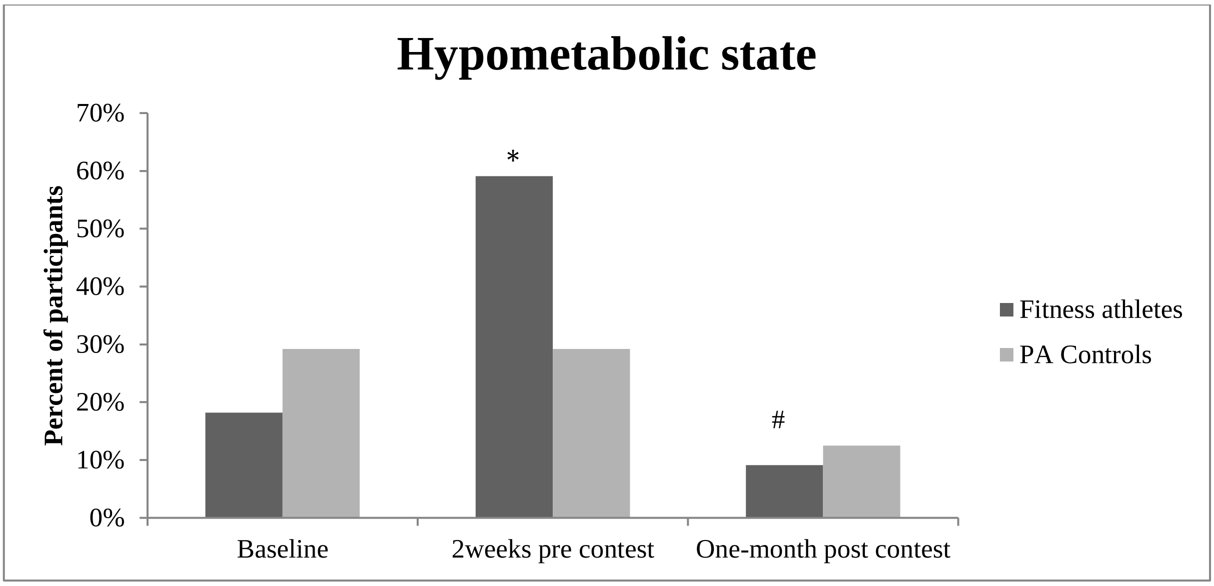

Figure 7: Proportion (%) of Fitness athletes and PA controls meeting the criteria for hypo metabolism at the three different screening points. Addjusted significance level was set to p<.016.

* Significant change (p<.001) in proportion of hypometabolic participants from baseline to 2 weeks pre contest

Significant change (p<.001) in proportion of hypometabolic participants from 2 weeks pre contest to one-month post contest.

4.3 Relationship between RMR and %BF

There is a weak to moderate correlation (r= .392) between RMR and percentage of body fat (%BF) in Fitness athletes two weeks pre contest (figure 8). A simple linear regression analysis shows that 15.4 % of resting metabolic rate can be explained by %BF. For each unit change in %BF, RMR will change with 19 kcal/day, i.e 1% decrease in %BF will result in a reduction in RMR of 19 kcal/day. This prediction is however not statistical significant (p=.71). The same analysis was conducted for PA controls, showing a weak, non-significant (p=.369) correlation (r=.192).

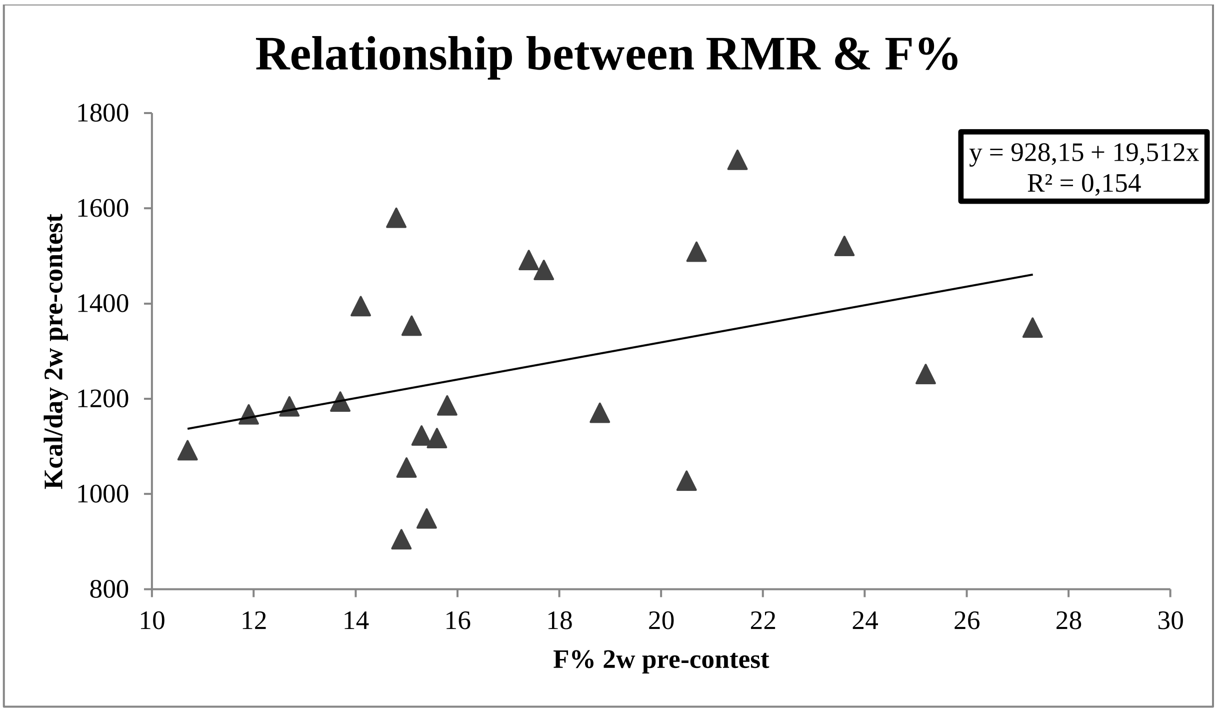

Figure 8: Linear relationship between RMR (kcal/day) and percentage of body fat in fitness athletes. Absolute values measured 2 weeks pre contest.

Analyses were also made for the relationship between RMRratio (i.e. ratio between measured and expected RMR) and percentages of change i %BF, weight change (kg) during the diet period and total %BF. No significant correlation was found between these variables, with p=.335, p=.813 and p=.109, respectively. Linear regression analysis was attempted, however, non of this analyses were statistical significant (p=.019, p=.335 and p=.813, respectively).

5.0 Discussion

The present study aimed to examine the effect of four months preparation leading up to a fitness competition on RMR in female fitness athletes; and whether or not a potential change in RMR would reverse when the fitness athletes returned back to a normal diet after a fitness competition.

A significant change in RMR was observed in fitness athletes before, during and after a fitness competition. RMR measured two weeks prior to the competition was significant lower compared to baseline, while one-month post competition, RMR values were returned back to baseline levels. There was also observed a significant increase in proportion of fitness athletes meeting the criteria for clinical low RMR throughout the preparation period. %BF was not seen as a statistical significant predictor on inter-individual change in RMR.

5.1 Change in resting metabolic rate

Due to Cohen´s (1988) interpretation of effect size, the result suggests a large effect (partial eta square =. 0.60) between the different points of measure. A significant decrease (-184 ±46 kcal/day, p=.002) in RMR was detected after four-month of dieting, and thus, there is significant evidence to reject the first null hypothesis, suggesting that four months of dieting leading up to a fitness competition will not result in any change in resting metabolic rate (RMR) in female fitness athletes aged 18-40 years. This result is similar to what is previously reported. The majority of studies examining RMR and weight loss show a decrease in RMR after weight loss (Alstrup et al., 1999; Body-Westphal et al., 2013; Fothergill et al., 2016; Kajioka et al., 2002; Martin et al., 2007; Stiegler & Cunliffe, 2006).

RMR was increased one-month post competition compared to 2 weeks pre contest (326 ±74 kcal/day, p=.001). However, there was no significant difference in mean RMR one-month post competition compared to baseline (p=.294), and thus, there is no significant evidence to reject the second null hypothesis, suggesting that a potential change in RMR will be reversed when fitness athletes return to a normal diet after a fitness competition. The literature shows various outcomes regarding RMR after weight regain. However, RMR seems to adapt to weight regain in a more beneficial extent in athletes and well-trained individuals compared to overweight and obese individuals. The difference in body composition and proportion of FFM between well-trained athletes and overweight and obese individuals may help explain the difference in RMR after weight regain. The crucial effect of FFM on change in RMR is suggested to be due to the higher metabolic rate in organs and muscular tissue (Nielsen et al., 2000).

The majority of research regarding RMR and weight regain after weight loss, is on overweight or obese individuals, while only a couple of studies have been targeting athletes. Hulmi and colleagues (2016) studied fitness athletes similar to our population. However, they examined hormonal changes during weight loss in female fitness athletes and did not measure RMR. They found that thriiodothyronine (T3) was significantly decreased due to the diet and stayed significant below baseline values after 3-4 months of recovery. The authors further points out that decreased levels of T3 may slow down the metabolic rate, and hence, might lead to lower RMR. Yet, RMR was not directly or indirectly measured and thus, this only remains an assumption. As FFM is crucial to avoid major decline in RMR and body composition in athletes is quite different from what seen in overweight and obese individuals, further research is necessary to fully understand the effect of weight loss and weight regain on RMR in athletes.

FFM is the biggest contributor to RMR, and a decrease in FFM is thought to affect RMR (Kenney, Wilmore & Costill, 2015; McArdle, Katch & Katch, 2015; Nielsen et al., 2000). One possible reason why athletes or well-trained individuals seems to adapt better to weight loss and weight regain, may be due to systematic resistance exercise, and thus a higher proportion of FFM. Melby and colleagues (1989) emphasize the metabolically differences between lean, well-trained athletes compared to obese dieters, and point out exercise as a crucial factor for the observed difference in RMR due to weight loss and regain in these two populations. When ten weight-classified athletes were examined during rapid weight loss followed by rapid weight regain, there were no significant change in BMR. However, in contrast to our study, these athletes lost 5% of BW within 7 days. They were also required to regain the lost weight within 12 hours of ab libitum eating. To achieve 5% weight loss in 7 days, drastic methods are used. Severe restrictive diets, combined with increased training volume and dehydration methods such as exercising with heating clothes and/or frequent use of sauna is common methods used by weight-classified athletes (Sagayama et al., 2014). Loss in total body water was seen as the main component of rapid weight loss followed by weight regain in these athletes, which may explain why no significant decrease in RMR was found. However, the authors point out the possibility that frequent WL and weight cycling may affect RMR to a greater extend. The majority of fitness athletes engaged in our study participated in a fitness competition for the first time. Hence, further research comparing first-time practitioners with experienced fitness athletes who have practiced this lifestyle for extended periods of time and thus experienced more periods of weight cycling could be of interest. Yet, Melby and colleagues (1989) found that despite several years of weight cycling, preseason RMR was higher in wrestlers compared to nonwrestlers without any history of weight cycling. Reasons for the discrepant findings are uncertain; thus, further research is required.

Melby and colleagues (1989) reported significant change in RMR in 26 competitive wrestlers before, during and after a wrestling season. Even though RMR was significantly suppressed during the season compared to baseline, RMR returned back to baseline levels 6 months after end of season. These results are similar to what was seen in fitness athletes. Exercise has been pointed out as a possible effect to explain the elevated levels of RMR after weight regain (Melby et al (1989). This is supported by other researchers, who suggest that when calorie restriction is accompanied by exercise, an offset of decline in RMR will occur (Molé et al., 1989). Type of exercise is also suggested to impact the rate of change in RMR due to calorie deficiency. Bryner et al (1999) found that there was a significant reduction in RMR (-211 kcal/day, $p<.05$) only in the diet + aerobic exercise group, while no significant reduction in RMR was found in the diet + resistance training group. The difference seen in RMR between D+AE and D+RT group, can be due to increased energy expenditure in D+AE and greater loss of FFM compared to what seen in D+RT group.

Resistance training is highly emphasized in fitness athletes. Continual resistance exercise before and after fitness competition may have an effect on preventing metabolic adaption and may possibly help explain why RMR returns to baseline levels one-month post competition. Melby and colleagues (1989) point out positive energy balance during weight regain as a contributor to raise RMR. This assertion is supported by Woods et al (2018), who reported that RMR values returned to baseline levels when energy availability was increased.

High-energy flux is assumed to increase levels of RMR (Bell et al., 2004; Melby et al., 2017). Elevated levels of RMR in high-energy flux are due to elevated energy expenditure from PA and exercise along with higher energy intake (increased thermic effect of food). Although high-energy flux is used when in energy balance, and fitness athletes intends to gain weight after the competition, the concept of high levels of PA and exercise along with increased energy intake is often seen in fitness athletes off-season. PA and exercise is a major part of the fitness lifestyle, even after the end of the competition period, thus, a potential explanation regarding RMR values that returned back to baseline one-month post contest, might be due to the high levels of PA and adequate energy intake after competition. High-energy flux is seen to be more beneficial to RMR compared to low-energy flux as cessation of exercise accompanied by low energy intake is associated with significantly decrease in RMR (Melby et al., 2017). This may also help explain the different findings regarding RMR in weight regain in athletes or well-trained individuals compared to those who are overweight and obese (Body-Westphal et al., 2013; Fothergill et al., 2016; Kajioka et al., 2002; Melby et al., 1989; Sagayama et al., 2014). It is plausible to think that athletes are more likely to have higher levels of PA and exercise along with a more healthy diet during a period of intended weight regain compared to overweight and obese individuals, and hence, observe an increase in RMR values back to baseline levels.

The relationship between RMR, weight loss and weight regain is interesting, not only for fitness athletes, but also for the general population. A global obesity epidemic is a fact in today´s society (WHO, 2017). In addition a well-trained and athletic body is seen as the ideal (Simpson & Mazzeso, 2016) Hence, there might be a high prevalence of individuals dieting to achieve weight loss and change in body composition, often inspired by approaches similar to what seen in fitness athletes. Resting metabolic rate is assumed to decrease in response to weight loss, and sometimes more than expected from loss of FFM and FM (Martin et al., 2007). As a result of calorie deficit, metabolic adaption occurs and RMR may decrease to a greather extend than what is expected (Martin et al., 2007). If RMR stay suppressed, but the energy intake remains the same, successful long-term weight loss may be challenging (Martin et al., 2007; Schwartz & Doucet, 2009).

5.2 Hypo metabolism

Figure 7 reveal a significant increase (p=.012) of 40.9% in proportion of fitness athletes with clinical suppressed RMR. Previous research regarding low energy availability report prolonged calorie deficiency to be associated with low %BF and FFM, along with decreased bone mineral density and other physiological and psychological changes, which are suggested to have negative health consequences (Sundgot-Borgen et al., 2013). Hulmi et al. (2016) reported that fitness athletes had more changes in menstrual function compared to women in the control group. Calorie deficit, combined with decreased %BF and especially low amounts of visceral adipose tissue are thought to reduce secretion of hormones relating to ovulation and menstrual bleeding (Hulmi et al., 2016).

According to our results, mRMR returned to pRMR one-month after the competition, where only 2 of the 22 athletes were hypometabolic. However, that does not offset the fact that preparations towards competing in fitness should be performed with caution due to suggested negative health effects. The findings in the present study regarding hypo metabolism show that even with an apparently optimal weight reduction; slow weight loss over time, enough macronutrients, and heavy resistance training, a decline in RMR cannot be avoided. Weight loss, both in fitness athletes and in the general population, should therefore always be done in cooperation with educated professionals. Extreme weight loss approaches should not be implemented over a long period of time, and only be periodized to special occasions or events, such as a fitness competition. Fitness athletes should also avoid long-term restrictions and return to a normal lifestyle with healthy diets and health enhancing exercise. Declined RMR is seen even among athletes undergoing continuous strength exercise (Melby et al., 1989). Thus, resistance training and adequate of intake macronutrients is not enough to prevent loss in RMR. Although previous researchers have found resistance exercise to increase RMR (Helms et al., 2014; Kirk et al., 2009), these studies were done on individuals in energy balance.

A body similar to what is seen in fitness athletes appears to be the body ideal in today´s society. Hence, a high proportion of the population are assumed to follow weight loss approaches, inspired by what is seen in fitness athletes preparing for a fitness competition, although they are not going to compete. So instead of 3-4 months of an extreme diet and exercise regimen, this approach is used as all year lifestyle. As we have seen in the result from the present study, 3-4 month of fitness preparation have a negative impact on health; thus, it can be assumed that following such a lifestyle over time will have negative consequences on health in the long term.

As an additional comment, the findings regarding proportion of fitness athletes with clinical low RMR two weeks pre contest could possibly have varied if different equations for pRMR had been used. RMRratio in the present study was calculated based on Harris & Benedict´s (1989) equation for prediction RMR. Flack et al. (2016) and Weijs & Vansant (2010) claim that Harris-Benedict equation has the highest accuracy towards mRMR (IC) compared to other equations. However, some research suggests that the Mifflin equation (Mifflin et al., 1990) has higher accuracy towards IC (Frankenfield et al., 2003).

5.3 Relationship between RMR and %BF

Previous studies suggest 60-80% of the change in RMR to be explained through FFM, yet, the remaining 15-40% is left unknown (Nielsen et al., 2000). Even though age and gender can account for some of the remaining inter-individual change, some cause of explanation remains uncertain (Nielsen et al., 2000). There is little consensus whether the proportion of fat mass affects inter-individual change in RMR (Cunningham, 1999; Dionne et al., 1999; Herbert et al., 2001; Nielsen et al., 2000). Even though the rate of oxygen consumption in adipose tissue is lower than in FFM, FM is suggested to contribute to RMR in some extent (Nielsen et al., 2000). Low %BF characterizes fitness athletes during the pre-contest phase and competition, and proportion of fat mass as an explanation to the observed change in RMR may therefore be of interest.

The results showed that there is a weak to moderate correlation (r=.392) between RMR and %BF. This is similar to what previously seen in non obese women (r=.55, p<.001, Nielsen et al., 2000; r=.21, p<.0, Herbert & Neuh., 2000). Simple linear regression analysis did not found any significant effect of %BM on RMR (p=0.71). Existing literature is varying. Some research suggests that FM is an independent predictor for RMR (Dionne et al., 1999; Nielsen et al., 2000), while others do not find any or only a small effect of %BF on RMR (Cunningham, 1999; Herbert & Neuh, 2001). Others suggest that FM only becomes a contributor to RMR when %BF rise above normal and thus only is a predictor to RMR in overweight or obese individuals due to their high amount of %BF and adipose tissue (Bosy-Westphal et al., 2008b; Nielsen et al., 2000). According to Cunningham (1999), the effect of %BF on RMR is absent in lean individuals.

Nielsen and colleagues (2000) found that 22% of the variation in RMR could be explained by variation in FM. This is slightly higher than the r^2 of .15 in our study, which was not significant (p=.71). This difference could possibly be explained by a higher mean FM (36 %BF) in the women who engaged in the study done by Nielsen et al (2000) compared to the fitness athletes in our study two weeks pre contest (17 %BF). It is further suggested that a large number of subject is required to detect any effect of FM on RMR (Nielsen et al., 2000), which may contribute to explain why there was no significant effect between %BF and RMR in study, due to small sample size.

Another proposal might be that FM only affects RMR when FM gets below a certain limit. Figure 8 reveal a large variation in RMR when the proportion of body fat is above 15%, while a %BF below 15% result in a smaller variation in RMR. It may seem like there is a detrimental effect on RMR when %BF in females drop below a certain level, but due to the small sample size it was not possible to study any such effect. Nonetheless, minimum healthy %BF in women is suggested to be between 12-15%, with 12%BF as the absolute minimum (McArdle, Katch & Katch, 2015; Meyer et al., 2013). One conceivable cause may be that %BF only affect RMR when %BF gets below recommendation levels for essential FM, due to metabolic adaptation that occurs as the body strives to save the energy storages. Three of the participants engaged in the present study had %BF <12, two weeks pre contest. In comparison, 6 out of 27 fitness athletes had a BF% <10 in the study done by Hulmi and colleagues (2016). However, in fitness athletes, low amounts of BF are usually only maintained for a short period, yet some practitioners tends to keep %BF low through the whole year (Hulmi et al., 2017). With these recommendations taken into consideration, it may seem rationally to suggest that further research should examine %BF and RMR in women with %BF <15 to further investigate the observed tendency. Yet, according to our findings, major deviations from pRMR are still seen in the athletes after the diet even though %BF is above 15%. This may indicate that there are negative health effects following fitness preparation and that both athletes and coaches should be aware of the possible negative impact participation might have on the individual.

Mean %BF among fitness athletes 2 weeks prior to the competition was 17.2%. This is higher than what seen in previous studies with female bodybuilders (McArdle, Katch & Katch, 2015; Van der Ploeg et al., 2001.) According to IFBB´s regulation, the proportion of fat mass (%BF) is required to be higher in bikini fitness, bodyfitness and athletic fitness compared to womens´ physique and bodybuilding where greater muscle sizes and a leaner and more defined body is emphasized (IFBB, 2017b; IFBB, 2017c; IFBB, n.da). Hulmi and colleagues (2016) reported mean %BF of 12.7 in 27 female fitness athletes the day after competition. However, RMR was not measured, nor was the relationship between %BF and RMR. The higher mean %BF found in our study, might be explained by the fact that the measures were conducted two weeks before the contest, while Hulmi et al (2016) performed measurement the morning after the competition. The last week before competition is characterized by low energy availability, and a lot of changes occurs both in the diet and in the athletes´ physique in order for the athletes to get rid of the last amount of body fat and get ready for the stage (Helm et al., 2014b). Thus, it may be assumed that mean %BF in our sample might have been lower if the measures had been conducted closer to or at the day of the competition when the fitness athletes were at their absolute lowest %BF and RMR.

Considering the observed trend that a relationship between %BF and RMR first seem to occur when %BF is below 15%, it can be thought that %BF is more crucial to RMR in fitness categories that requires a leaner body. However, it is important to notice that the results from the present study show a mean decrease in RMR even though mean %BF is above 15%, which indicates a negative health effect even when %BF is above the crucial limit.

Some research suggests that FM is a greater predictor to RMR in men compared to women (Dionne et al., 1999). In contrast Nielsen and colleagues (2000) indicate that FM appears to be a bigger predictor for inter-individual change in RMR in women than in men. The different findings might be due to varied sample size, different gender distribution or diverse rage of body size. Nielsen et al (2000) examined a broad range of body sizes (mean BMI was 24.3), had 2.5 times lager sample size compared to Dionne et al (1999) and had a higher share of women. The study done by Dionne and colleagues (1999) was conducted in overweight men and women (mean BMI of 29.0). The present study only examines women, and further research should include male fitness athletes to detect whether or not %BF as a predictor for RMR differs between men and women. However, due to its relatively small effect, a bigger sample size as well as a broader range of %BF is required to detect any potentially effect on RMR (Nielsen et al., 2000). The sample size of in our study is quite small and the population is quite homogenous regarding %BF, which may help explain why no significant effect was found.

Due to no significant findings regarding absolute %BF and RMR, additional analyses were conducted to further investigate potential predictors for RMR. Percentages of change i %BF, weight change (kg) during the diet period and total %BF were tested as predictors for RMRratio (i.e. ratio between mRMR and pRMR). None of these variables were significant correlated. Observing the r^2 values, absolute %BF (figure 8) appears to explain the change in RMR to a greater extent than a change in %BF or BW. Ie. It seems to be low %BF (below recommended BF levels in females), rather than the change or decrease in %BF that may help explaine the decrease in RMR. However, it is crucial to highlight that even though the regression analysis suggest %BF to explain 15.4% of the inter-individual change in RMR, the effect was not statistical significant and further research is required to explain change in RMR after weight loss.

5.4 Strengths and limitations

There are both strength and limitations with the present study. RMR was measured by indirect calorimetry, which is considered the gold standard in practical and clinical settings (Haugen, Chan & Li, 2007). Participants were instructed to meet fasting, however, we did not control this before measures. Thus, we cannot be completely sure whether or not RMR values were affected by metabolism. There are few studies examining weight loss with a following intended weight regain that includes a control group. This must be seen as strength with the present study. There were no significant differences between the two groups at baseline, which allow us to compare the changes in fitness athletes with a similar group of controls that did not change their diets or exercise during the study.

The small sample size however is a limitation with the study. Even though Flack et al., (2016) and Reeves et al., (2004) suggest a sample size of 21-29 to detect 90% power at 95% significant level, the sample size seem to be too small to detect various effects on RMR. However, compared to previous research done on bodybuilders (McArdle, Katch & Katch, 2015; Van der Ploeg et al., 2001), where only 5-10 athletes have been investigated, the sample size in the present study (n=22) seems to be a step in the right direction to increase the knowledge on this population. Hulmi et al. (2016) presented similar sample size in their study, with 27 competitive female fitness athletes. There are some limitations regarding the study design. The first screening took place four months before the competition (equivalent to one month before the preparatory diet starts). However, we do know that some fitness athletes start their diet more than three months prior to a competition. The majority of the participants had no competition experience prior to this study; hence, it is possible that three months of diet and preparation is insufficient for some athletes. Some athletes may be following a diet for several months before they enter the stage. This was not controlled for in the present study, and baseline measures may therefore not be completely accurate. In addition, the second screening took place two weeks prior to the contest, to allow the participants to completely focus on the last preparations. However, we do know that the last week in advance of the competition is quite extreme regarding energy availability (Helms et al., 2014b), thus, it could have been interesting to conduct the measures when the athletes were at the absolute minimum regarding BW, %BF, RMR and energy deficit.

Due to the distinctive and physically prominent effect of fitness, blinding has not been accomplished. Especially during the second screening, right before competition, when the fitness athletes were noticeably leaner than PAcontrols, it was quite obvious whether the subject was a fitness athlete or a PA control. In addition, the ID numbers indicated whether the subject belonged to the fitness- or control group.

Simple linear regression analysis was performed to predict the relationship between variables that might affect RMR. The number of subject required to conduct a linear regression analysis is controversial. However, a minimum of 10-20 subjects for each independent variable is suggested to be sufficient (Harrel, 2013; Schmidt, 1971). Austin & Steyerberg (2015), suggest as little as two subjects per predictor to adequate estimate regression coefficients. Yet, a bigger sample size is preferred.

5.5 Further research

More research is needed to determine the mechanisms of RMR during weight loss and after weight regain. The complete causes and mechanisms of inter-individual change in RMR should further be examined to fully understand the change in RMR during weight loss and weight regain. Research aiming to detect whether or not there are differences between first-time practitioners and experienced fitness athletes with several periods of weight cycling could also be of interest. Furthermore, investigation regarding the effect of %BF on RMR in lean women shoud be conducted. Studies examining the relationship between %BF and RMR in fitness athletes with %BF below 15 would be of interest to observe whether there is a stronger relationship between these two variables when %BF is below what is considered as healthy for females (McArdle, Katch & Katch, 2015; Meyer et al., 2013). In addition, more research on fitness athletes, including both men and women, and with a bigger sample size is crucial to further understand both the physiological and psychological effects of a fitness lifestyle. Longer follow-up period is preferable to detect any long-term consequences. To ensure that no artificial performance-enhancing supplements or methods are the underlying cause of change, blood samples would be desirable in future research in this population.

6.0 Conclusion

A significant change in RMR was observed in fitness athletes after four months of dieting leading up to a fitness competition. A high proportion of fitness athletes had clinical suppressed RMR at the end of the diet period, which is associated with various negative consequences on health. However, RMR values were reversed back to normal levels one-month after competition, suggesting that extreme weight loss approaches should not be implemented over a long period of time, and only be periodized to special occasions or events, such as a fitness competition. This should always be done in cooperation with educated professionals to ensure minimal detrimental impact on the health of the individual.

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List of tables

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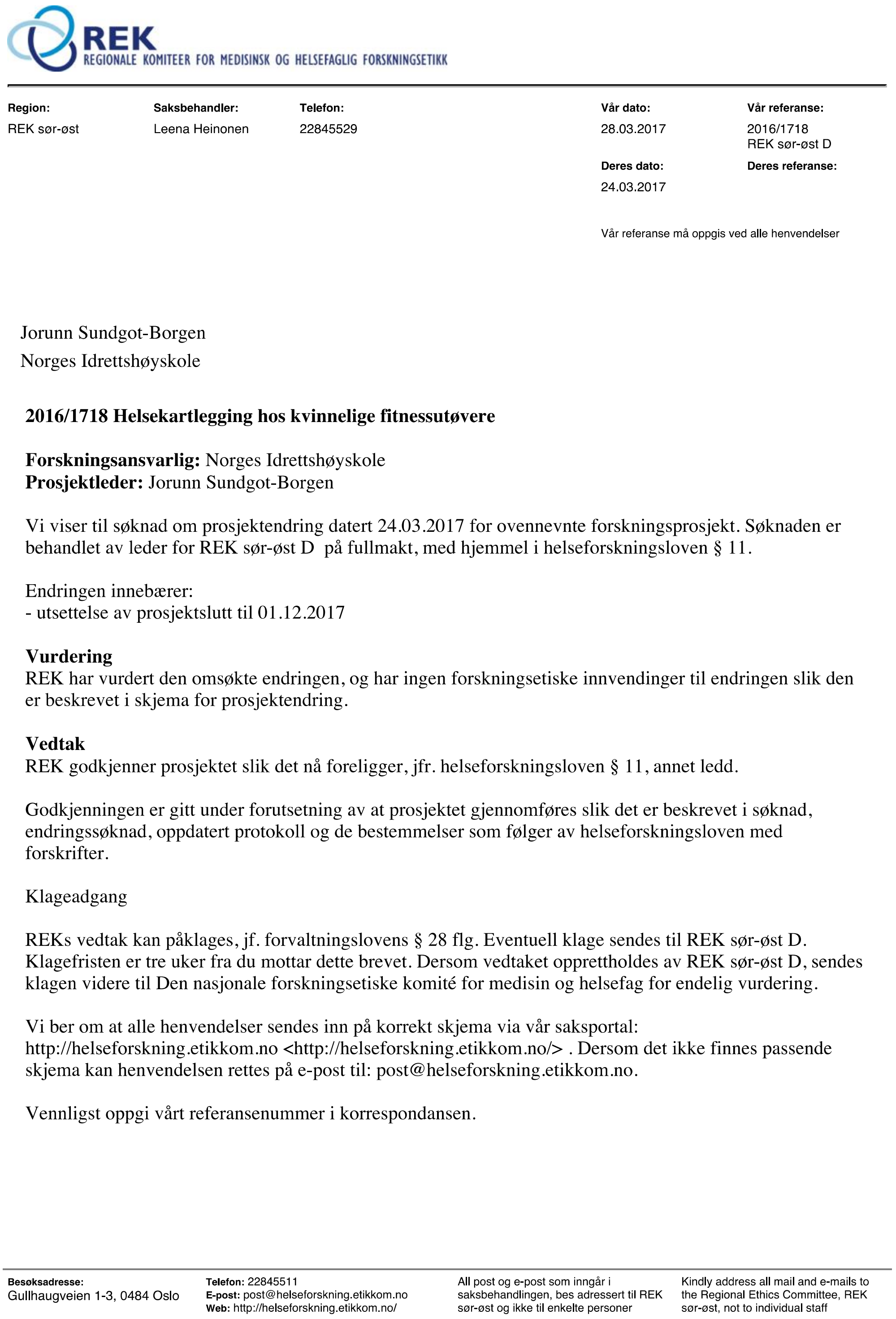
Appendix

Appendix 1



REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Leena Heinonen	22845529	28.03.2017	2016/1718 REK sør-øst D

Deres dato: 24.03.2017
Deres referanse:

Vår referanse må oppgis ved alle henvendelser

Jorunn Sundgot-Borgen
Norges Idrettshøyskole

2016/1718 Helsekartlegging hos kvinnelige fitnessutøvere

Forskningsansvarlig: Norges Idrettshøyskole
Prosjektleder: Jorunn Sundgot-Borgen

Vi viser til søknad om prosjektendring datert 24.03.2017 for ovennevnte forskningsprosjekt. Søknaden er behandlet av leder for REK sør-øst D på fullmakt, med hjemmel i helseforskningsloven § 11.

Endringen innebærer:
- utsettelse av prosjektslutt til 01.12.2017

Vurdering
REK har vurdert den omsøkte endringen, og har ingen forskningsetiske innvendinger til endringen slik den er beskrevet i skjema for prosjektendring.

Vedtak
REK godkjenner prosjektet slik det nå foreligger, jfr. helseforskningsloven § 11, annet ledd.

Godkjenningen er gitt under forutsetning av at prosjektet gjennomføres slik det er beskrevet i søknad, endringssøknad, oppdatert protokoll og de bestemmelser som følger av helseforskningsloven med forskrifter.

Klageadgang

REKs vedtak kan påklages, jf. forvaltningslovens § 28 flg. Eventuell klage sendes til REK sør-øst D. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst D, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Vi ber om at alle henvendelser sendes inn på korrekt skjema via vår saksportal: http://helseforskning.etikkom.no <http://helseforskning.etikkom.no/> . Dersom det ikke finnes passende skjema kan henvendelsen rettes på e-post til: post@helseforskning.etikkom.no.

Vennligst oppgi vårt referansenummer i korrespondansen.

Besøksadresse:
Gullhaugveien 1-3, 0484 Oslo

Telefon: 22845511
E-post: post@helseforskning.etikkom.no
Web: http://helseforskning.etikkom.no/

All post og e-post som inngår i saksbehandlingen, bes adressert til REK sør-øst og ikke til enkelte personer

Kindly address all mail and e-mails to the Regional Ethics Committee, REK sør-øst, not to individual staff

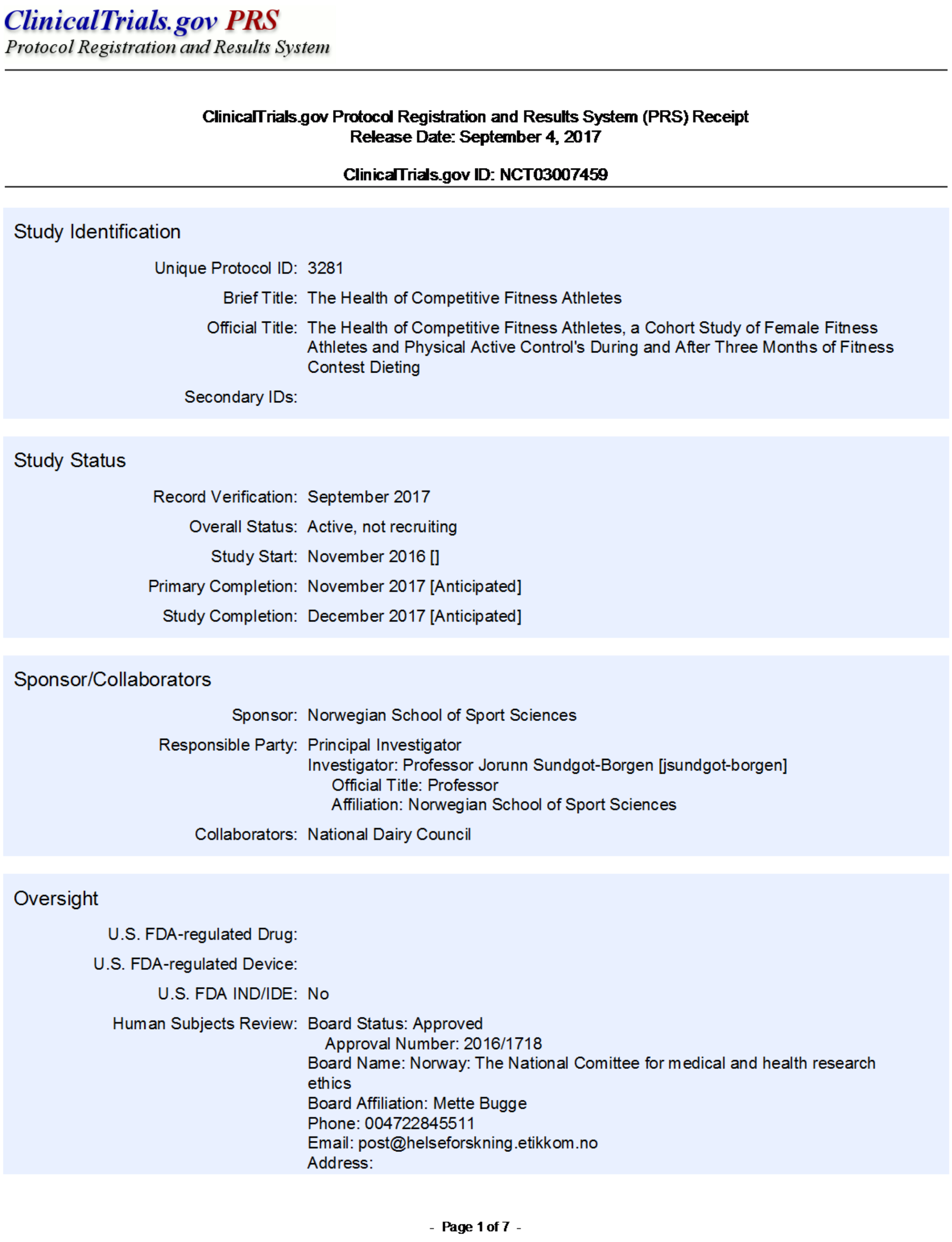
Med vennlig hilsen

Finn Wisløff
Professor em. dr. med.
Leder

Leena Heinonen
rådgiver

Kopi til: *Jorunn.sundgot-borgen@nih.no*
Norges idrettshøgskole ved øverste administrative ledelse:
postmottak@nih.no

Appendix 2



ClinicalTrials.gov PRS
Protocol Registration and Results System

ClinicalTrials.gov Protocol Registration and Results System (PRS) Receipt
Release Date: September 4, 2017

ClinicalTrials.gov ID: NCT03007459

Study Identification

Unique Protocol ID: 3281

Brief Title: The Health of Competitive Fitness Athletes

Official Title: The Health of Competitive Fitness Athletes, a Cohort Study of Female Fitness Athletes and Physical Active Control's During and After Three Months of Fitness Contest Dieting

Secondary IDs:

Study Status

Record Verification: September 2017

Overall Status: Active, not recruiting

Study Start: November 2016 []

Primary Completion: November 2017 [Anticipated]

Study Completion: December 2017 [Anticipated]

Sponsor/Collaborators

Sponsor: Norwegian School of Sport Sciences

Responsible Party: Principal Investigator
Investigator: Professor Jorunn Sundgot-Borgen [jsundgot-borgen]
Official Title: Professor
Affiliation: Norwegian School of Sport Sciences

Collaborators: National Dairy Council

Oversight

U.S. FDA-regulated Drug:

U.S. FDA-regulated Device:

U.S. FDA IND/IDE: No

Human Subjects Review: Board Status: Approved
Approval Number: 2016/1718
Board Name: Norway: The National Comittee for medical and health research ethics
Board Affiliation: Mette Bugge
Phone: 004722845511
Email: post@helseforskning.etikkom.no
Address:

Gullhaugveien 1-3, 0484 Oslo, Norway
Data Monitoring: No
FDA Regulated Intervention: No

Study Description

Brief Summary: Fitness athletes emphasize the value of staying lean, muscular and defined, and motivates and inspires followers through social media. We want to study the effect of such lifestyle on selected aspects of psychological and physical health in female fitness athletes, and compare the outcomes to a healthy, physically active female population.

Detailed Description: Little is known about the mental and physical health effect from following the modern, idealized fitness lifestyle. The lifestyle is characterized by selective and restrictive eating behavior, strength training and use of supplements. The athletes emphasize the value of staying lean, muscular and defined, and motivates and inspires followers through social media. This study will recruit and observe a group of competitive female fitness athletes over their typical 3 month dieting period when preparing for contest. Before their contest diet is initiated, the athletes will be screened on selected aspects of psychological and physical health. The screening is repeated two weeks prior to their first seasonal contest, and then finally one month post-contest season. During the diet period of 3 months, the athletes answers brief questionnaires by email on eating- and training behavior and on mood, while also reporting dietary intake by telephone interview.

Recreational physically females, not planning to do any fitness contest, will be recruited to serve as a parallel control group. They will perform the same physical and psychological screening, and answer the same questionnaires throughout the fitness contest diet period.

Conditions

Conditions: Resting Metabolic Rate
Bone Mineral Density, Low, Susceptibility to
Body Image
Perfectionism
Depression
Eating Disorder
Exercise-Related Amenorrhea
Exercise Addiction
Binge Eating
Dietary Amenorrhea
Dietary Deficiency

Keywords: Body composition
Bone mineral density
Binge Eating
Eating Disorder
Exercise Dependency
Depression
Perfectionism
Body building
Drive for Muscularity
Drive for leanness

Study Design

Study Type:	Observational
Observational Study Model:	Case-Control
Time Perspective:	Prospective
Biospecimen Retention:	None Retained
Biospecimen Description:	
Enrollment:	47 [Actual]
Number of Groups/Cohorts:	2

Groups and Interventions

Groups/Cohorts	Interventions
Female Fitness Athletes Psychological health and physiological health of fitness athletes	Psychological health Observing and measuring baseline, and changes in, psychological health through a fitness contest preparation period Physiological health Observing and measuring baseline, and changes in, physiological health through a fitness contest preparation period
Female, physically active Controls Psychological health and physiological health of female controls	Psychological health Observing and measuring baseline, and changes in, psychological health through a fitness contest preparation period Physiological health Observing and measuring baseline, and changes in, physiological health through a fitness contest preparation period

Outcome Measures

Primary Outcome Measure:

1. Body composition
   Baseline values, change from pre-test to mid-test, and finally change from mid- to post-test, for lean body mass and fat mass, measured with Dual Xray absorptiometry (DXA)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]

Secondary Outcome Measure:

2. Resting Metabolic Rate
   Baseline values, change from pre-test to mid-test, and finally change from mid- to posttest, for resting metabolic rate, measured with indirect calorimetry

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
3. Bone Mineral Density
   Baseline values, change from pre-test to mid-test, and finally change from mid- to post-test, for bone mineral density measured with Dual Xray absorptiometry (DXA)

[Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]

4. Perfectionism
   Comparing scores on perfectionism between case and controls, and individual changes in scores through study period, with Child Adolescent Perfectionism Scale (CAPS 22 items)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
5. Depression
   Baseline values, change from pre-test to mid-test, and finally change from mid- to post-test, for scores on depressive mood, measured with Becks Depression Inventory (BDI)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
6. Eating disorders
   Baseline values, change from pre-test to mid-test, and finally change from mid- to post-test, for scores on Eating disorder examination questionnaire (EDE-q)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
7. Eating behavior; binge eating
   Baseline values, change from pre-test to mid-test, and finally change from mid- to post-test, for scores on Binge Eating Scale (BES)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
8. Eating behavior; restrictive eating and sensation of hunger
   Baseline values, change from pre-test to mid-test, and finally change from mid- to post-test, for scores on Three Factor Eating Questionnaire (TFEQ-21)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
9. Menstrual Status, self-reported
   Baseline status, change from pre-test to mid-test, and finally change from mid- to post-test, for self-reported menstruation health (Low Energy Availability in Females questionnaire, LEAF)

   [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
10. Dietary intake, weighed diet registration
    Change in dietary intake. Baseline status, change from pre-test to mid-test, and finally change from pre- to post-test, evaluated with weighed dietary registration and analysed with national analytical software (Kostholdsplanleggeren.no)

    [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
11. Exercise dependency
    Baseline status, change from pre-test to mid-test, and finally change from pre- to post-test, evaluated with Exercise Dependency Scale (EDS)

    [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
12. Reason for Exercise
    Baseline status, change from pre-test to mid-test, and finally change from pre- to post-test, evaluated with Reason for Exercise Inventory (REI)

    [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
13. Depression
    Changes in reported state of depression during the dieting period of fitness athletes, measured with BDI

[Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]

14. Dietary intake, 24-hour recall interview
    Changes in energy and nutrient intake during the dieting period of fitness athletes, measured with dietary 24-hour recall interview and analysed with national analytical software (Kostholdsplanleggeren.no)

    [Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
15. Menstrual cycle, self reported
    Self reported menstrual bleeding's during the dieting period of fitness athletes (LEAF)

    [Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
16. Eating disordered behavior
    Changes in eating behavior during the dieting period of fitness athletes, measured with the behavioral aspects of EDE-q

    [Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
17. Eating behavior; binge eating behavior
    Changes in eating behavior during the dieting period of fitness athletes, measured with BES

    [Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
18. Eating behavior; restrictive eating and sensation of hunger
    Changes in eating behavior during the dieting period of fitness athletes, measured with TFEQ-21

    [Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
19. Training volume, self reported
    Reporting number of training sessions pr week and type of exercise (endurance related exercise or strength training)

    [Time Frame: Each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
20. Training history, self reported
    Reporting experience with training, giving details on specific sport activity and typical intensity

    [Time Frame: Retrospective]
21. Dietary Supplements
    Reporting usage of dietary supplements during the dieting period

    [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest), and each 2nd week during the 3 month contest dieting period (between pre-test and mid-test)]
22. Eating disorders, history
    Reporting previous eating disorder and whether treatment were recieved or not

    [Time Frame: Retrospective]
23. Drive for Muscularity
    Baseline status, change from pre-test to mid-test, and finally change from pre- to post-test, evaluated with Drive for Muscularity (DM) (McCreary & Sasse 2000)

    [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
24. Drive for Leanness
    Baseline status, change from pre-test to mid-test, and finally change from pre- to post-test, evaluated with Drive for Leanness (DL) (Smolak & Murnen 2008)

    [Time Frame: Pre-test (3 months before contest), mid-test (2 weeks before contest) and post-test (one month post-contest)]
25. Body Weight, history
    Reporting lowest and highest bodyweight after 18 yr's of age (excluding periods of pregnancy)

    [Time Frame: Retrospective]

Eligibility

Study Population: Female, fitness athletes are being recruited through social media, Fitness team leaders and the Norwegian national federation for Bodybuilding and Fitness. Physically active, female controls are being recruited through social media, training facilities and through colleagues at the Norwegian School of Sport Sciences

Sampling Method: Non-Probability Sample

Minimum Age: 18 Years

Maximum Age: 40 Years

Sex: Female

Gender Based:

Accepts Healthy Volunteers: Yes

Criteria: Inclusion Criteria:

- Fitness athletes: planning to compete in fitness sport during spring or fall 2017
- Controls: being regular physically active (exercise >2 times/week during last year) with a BMI between 17,5-30

Exclusion Criteria:

- Controls: having competed in fitness sports previously or planning to do in the future, or working as a personal trainer.
- Not able to meet at the Norwegian School of Sport Sciences for baseline and follow up screenings.
- Being pregnant or nursing
- Metabolic related diseases

Contacts/Locations

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Study Officials: Jorunn K Sundgot-Borgen, Professor
Study Director
Professor

Locations: Norway
Norwegian School of Sports Sciences
Oslo, Norway, 0806
Contact: Jorunn Sundgot-Borgen, Phd 92241745 Ext. +47 jorunn.sundgot-borgen@nih.no
Principal Investigator: Therese F Mathisen, MSc

IPDSharing

Plan to Share IPD: No

Individual participant data are not planned to be available to other than the research group.

References

Citations:

Links:

Available IPD/Information:

Appendix 3

Forespørsel om deltakelse i forskningsprosjekt

"Kartlegging av helse hos fitnessutøvere"

Bakgrunn og formål
I dette forskningsprosjektet er hensikten å kartlegge fysisk og psykisk helsetilstand hos et utvalg aktive, kvinnelige fitnessutøvere i den typiske grunn-treningsperiode, samt gjennom en periode med konkurranseforberedelser (normalt 3-4 mnd. før en konkurranse). Formålet er å øke kunnskap om hvordan en slik livsstil, med de trenings og kostholds regimer som benyttes, påvirker de kvinnelige utøvernes helsetilstand. Vi vet for lite om effekten av slik idealisert, sunn livsstil på fysisk og psykisk helse. Det finnes ingen objektive data som forteller hvordan utøverne faktisk har det.
Svar og resultater som fremkommer fra denne undersøkelsen vil bli sammenlignet med en gruppe ikke-konkurrerende, men fysisk aktive kvinner i samme aldersgruppe (kontroll personer).
Prosjektet gjennomføres som en mastergrad ved Norges Idrettshøyskole, og veiledes av prosessor Jorunn Sundgot-Borgen og doktorgradsstipendiat Therese Fostervold Mathisen.

Du forespørres om deltagelse i dette kartleggingsstudiet, fordi du er kvinne mellom 18 og 40 år, trener for fitnesskonkurranser, har oppgitt til din klubb og/eller forbund at du planlegger og stille i vårens konkurranser for 2017, og fordi du har tatt kontakt med oss etter å ha sett våre rekrutterings utlysninger.

Hva innebærer deltakelse i studien?
Deltagelse i dette kartleggingsstudiet innebærer at du samtykker i å besvare et spørreskjema før og etter oppstart av konkurranse-diett, samt å besvare et spørre skjema annenhver uke i den perioden hvor du følger din diett fram til konkurranse (~12 uker totalt). Spørreskjemaet distribueres pr email og besvares elektronisk. Du vil få spørsmål om å besvare spørreskjemaet 8 ganger pr mail. Ved første besvarelse (november/desember), samt en uke *før* første konkurranse (mars-april), og til slutt en måned *etter* siste konkurranse (april-mai), bes du i tillegg om å møte ved Norges Idrettshøyskole. Der blir du kartlagt via røntgenbilde, *dual-energy x-ray absorptiometry* (DXA), og indirekte kalorimetri. DXA er forskningens og klinikkens gullstandard for måling av skjeletthelse samt for kroppssammensetning (fettprosent og andel muskelmasse), mens indirekte kalorimetri er gullstandard for måling av hvilestoffskifte. Ved oppmøte gir vi også en kort innføring i hvordan du i de fire neste påfølgende dager registrerer ditt kosthold, for senere kostholdsanalyser i vår lab.
Dine besvarelser oppbevares elektronisk og avidentifiseres, slik at du på ingen måte kan kobles til besvarelsene/resultatene.

Hva spør vi om i Spørreskjemaet
Via spørreskjemaet som du besvarer vil vi kartlegge utvalgte deler av din fysiske og psykiske helse. Spørsmålene handler i hovedsak om din treningshistorie, forekomst av skader, menstruasjon og bruk av hormonelle prevensjonsmidler, dine opplevde krav til deg selv og fra andre, hvordan du har det, hvordan humøret ditt er, din motivasjon for- og forhold til, trening, ditt forhold til mat og sult, samt ditt forhold til din egen kropp.

Hva er DXA?
DXA kan sammenlignes med å ta et vanlig røntgenbilde, men innebærer her at maskinen er i bevegelse mens du ligger rolig på en benk. Dette kan ikke kjennes fysisk.

Indirekte kalorimetri
Målingen innebærer å ligge avslappet på en madrass i rolige omgivelser, med en ansiktsmaske som dekker munn og nese. Vi måler din gassutveksling (innpust/utpust) og måleperioden tar totalt 30 min å gjennomføre.

Kostholdsregistrering og kostholdsintervju
Kostholdsregistrering innebærer å veie og notere ned all mat og drikke du inntar i 4 kontinuerlige dager. Dette gjennomføres ved første kartlegging før diett oppstart, rett før konkurranse, og ved siste kartlegging etter konkurranse. Vi bruker informasjonen til å analysere energi- og næringsstoffinntaket ditt ved hjelp av en dataprogramvare. Kostholds intervju gjøres til samme tider som besvarelse av spørreskjema gjennom selve diettperioden, og innebærer å redegjøre for alt mat- og drikke inntatt gjennom siste døgnet, ved å angi mengder i form av husholdningsmål (dl, ss, stk) eller evnt vektenhet dersom det er aktuelt.

Hva skjer med informasjonen om deg?
Alle personopplysninger vil bli behandlet konfidensielt. Kun to involverte master grads studenter og de to veilederne (som har taushetsplikt) vil ha tilgang til informasjon som gis og målinger som gjøres. Din identitet kobles til et avidentifisert id-nummer, og listene med slik koblings-oversikt oppbevares adskilt fra øvrige data, kun tilgjengelig for prosjektansvarlig.

Prosjektet skal etter planen avsluttes sommeren 2017. Informasjon som er fremkommet i studien ivaretas avidentifisert i våre elektroniske arkiv. Koblingslisten mellom ditt navn og tildelt id-nummer slettes etter at prosjektperioden er over.

Frivillig deltakelse
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(Signert av prosjektdeltaker, dato)

Forespørsel om deltakelse i forskningsprosjekt

"Kartlegging av helse hos fitnessutøvere"

Bakgrunn og formål
I dette forskningsprosjektet er hensikten å kartlegge fysisk og psykisk helsetilstand hos et utvalg aktive, kvinnelige fitnessutøvere i den typiske grunn-treningsperiode, samt gjennom en periode med konkurranseforberedelser (normalt 3-4 mnd før en konkurranse). Formålet er å øke kunnskap om hvordan en slik livsstil, med de trenings og kostholds regimer som benyttes, påvirker de kvinnelige utøvernes helsetilstand. Vi vet for lite om effekten av slik idealisert, sunn livsstil på fysisk og psykisk helse. Deet finnes likevel ingen objektive data som forteller hvordan utøverne faktisk har det.
I denne type forskning er det viktig å ha en kontrollgruppe (andre kvinner i samme aldersgruppe som er fysisk aktive, men som IKKE konkurrerer i fitness) for å sammenligne med studiegruppen (kvinner som konkurrerer i fitness). Det er i denne forbindelse at du forespørres om deltagelse i prosjektet. Prosjektet gjennomføres som en mastergrad ved Norges Idrettshøyskole, og veiledes av prosessor Jorunn Sundgot-Borgen og doktorgradsstipendiat Therese Fostervold Mathisen.

Du forespørres altså om deltagelse i dette kartleggingsstudiet, fordi du er kvinne mellom 18 og 40 år, har en BMI mellom 17,5 og 30, trener aktivt for egen interesse, konkurrerer ikke aktivt i noen idrett, og har tatt kontakt med oss etter å ha sett våre rekrutterings oppslag i ditt treningsmiljø og/eller i sosiale medier.

Hva innebærer deltakelse i studien?
Deltagelse i dette forskningsprosjektet innebærer at du samtykker i å besvare et spørreskjema før og etter oppstart av konkurranse-dietten til de omtalte, samt å besvare et spørre skjema annenhver uke i den perioden hvor fitnessutøverne følger sin diett fram til konkurranse (~12 uker totalt). Spørreskjemaene distribueres pr email og besvares elektronisk. Du vil få spørsmål om å besvare spørreskjemaet 8 ganger pr mail. Ved første besvarelse (november/desember), samt en uke *før* første fitness konkurranse (mars-april), og til slutt en måned *etter* siste fitness konkurranse (april-mai), bes du i tillegg om å møte ved Norges Idrettshøyskole. Der blir du kartlagt via røntgenbilde, *dual-energy x-ray absorptiometry* (DXA), og indirekte kalorimetri. DXA er forskningens og klinikkens gullstandard for måling av skjeletthelse samt for kroppssammensetning (fettprosent og andel muskelmasse), mens indirekte kalorimetri er gullstandard for måling av hvilestoffskifte. Ved oppmøte gir vi også en kort innføring i hvordan du i de fire neste påfølgende dager registrerer ditt kosthold, som senere analyseres i vår lab.
Dine besvarelser oppbevares elektronisk og avidentifiseres, slik at du på ingen måte kan kobles til besvarelsene/resultatene.

Spørsmålsskjema
Via spørreskjemaet som du besvarer vil vi kartlegge utvalgte deler av din fysiske og psykiske helse. Disse handler i hovedsak om din treningshistorie, forekomst av skader, informasjon om menstruasjon og bruk av hormonelle prevensjonsmidler, informasjon om dine opplevde krav til deg selv samt opplevde krav fra andre, hvordan du har det/ved hvilket humør du er, din motivasjon for, og forhold til, trening, ditt forhold til mat og sult, samt ditt forhold til din egen kropp.

DXA
DXA kan sammenlignes med å ta et vanlig røntgenbilde, men innebærer her at maskinen er i bevegelse mens du ligger rolig på en benk. Dette kan ikke kjennes fysisk.

Indirekte kalorimetri
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