 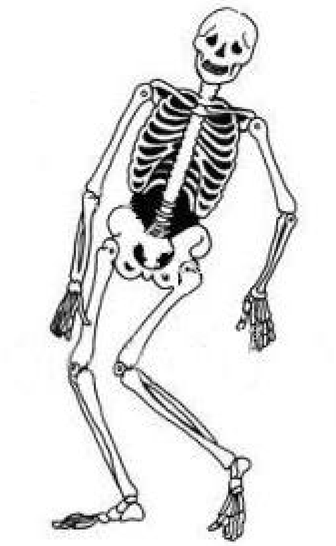

3 MEALS **6 MEALS**

MEAL FREQUENCY, STRENGTH-TRAINING AND BODY COMPOSITION

The Meal Frequency Project

The effect of meal frequency on body composition during 12-weeks of strength training

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Abbreviations

1RM – 1 Repetition Maximum

3M group – 3 meals per day group

6M group – 6 meals per day group

BMD – Bone Mineral Density

BW – Body Weight

CHO – Carbohydrate

DEXA – Dual Energy X-ray Absorbtiometry

E – energy in kJ

EAA – Essential Amino Acid

LBM – Lean Body Mass

MRI – Magnetic Resonance Imaging

NEAA – Non-Essential Amino Acids

NIF/OLT – The Norwegian Olympic Committee and Confederation of Sports

NIH – Norwegian School of Sports Sciences

NMR – Nuclear Magnetic Resonance

RMR – Resting Metabolic Rate

UIO – University of Oslo

xRM – x Repetition Maximum, x representing the number of repetitions

Abstract

Background: Human trials on the effect of meal frequency on body composition are scarce. Short-term studies show increased rate of protein synthesis immediately after intake of amino acids (Rennie 2002), and frequent meals are shown to aid in the preservation of lean body mass when dieting (Iwao 1996). Consequently it could be hypothesised that in response to strength training interventions, more frequent meals will give larger muscle mass accumulation and lower fat mass than fewer meals.

Objective: The purpose of this study was to compare the effects of dividing the daily food intake in 3 versus 6 meals per day on changes in body composition in young men and women performing strength training over 12 weeks.

Design: Men (n=33) and women (n=15) aged 21 to 35 with at least one year of previous strength training experience were matched according to strength and gender and then randomly assigned to either a 6M group or a 3M group. The prescribed total dietary intake was equal between the groups and was calculated to give a positive energy balance of approximately 1200 KJ/day, a protein intake of 1.5-1.7 g/kg/day and a carbohydrate intake of 5-7 g/kg/day (Table 1). During the training period the dietary intake was controlled by repeated 24-hours recalls. All participants performed the same periodized 2-split strength-training programme, training four times per week, giving each muscle group one heavy session and one light session per week. In the heavy sessions, training intensity varied between 10 and 3 RM sets, and 3-6 sets were performed in each exercise. Project leaders, giving every participant the necessary assistance, supervised all heavy sessions. Determination of body composition was performed with DEXA at the beginning of, in the middle of and immediately after the trial.

Results: A total of 16 men and 11 women completed the project. The 3M group had a strong tendency towards greater gain in LBM than the 6M group after twelve weeks of strength training, 1.71% {-0.18, 3.59}, p=0,075. After linear regression analysis the difference was significant when adjusted for gender and energy intake (p=0.045), when adjusted for gender and protein intake (p=0.027), and when adjusted for gender, protein intake, carbohydrate intake and fat intake (p=0.011). There were no significant differences in change in fat mass between the groups, but a tendency towards a greater gain in the 3M group, 7.33% {-5.23, 19.90}, p=0.241. The 3M group had a 2.87% {0.62, 5.12} larger weight gain than the 6M group, p=0.014. Both groups had significant increases in strength in all test exercises. The 3M group had a larger strength gain in bench press, 10.85% {3.38, 18.32}, p=0.006 and triceps pushdown, 12.81%, {3.14, 22.47}, p=0.011 and a larger strength gain for the upper body, 8.37% {1.61, 15.13}, p=0.017 and total body, 6.28 {0.46, 12.09}, p=0.035 than the 6M group. The participants had a 2.31% {0.83, 3.79}, gain in bone mineral density of the spine during the twelve weeks of strength training, p=0.003, but there were no differences between the groups.

Conclusion: In this study, three meals per day resulted in larger muscle- and strength gain from strength training when in positive energy balance than six meals per day over a period of twelve weeks. The reason why we draw opposite conclusions from short-term studies needs further investigation. More long-term studies are needed to determine the optimal meal frequency for ultimate gain in LBM from strength training, and larger groups may be needed to determine an effect of meal frequency on fat mass. The changes in fat mass had large variations within and between the groups, making it difficult to draw any conclusions.

Key words: Meal frequency, strength training, lean body mass, fat mass, bone mineral density, DEXA.

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1. Introduction

During recent years specific intakes of protein, carbohydrate and energy in association with training have been recommended (Mat og prestasjon 2003). Much research has been done with particular regard to endurance sports, and focus has been on the importance of the diet's composition, sources of energy and protein and meal frequency and timing for optimal glycogen re-synthesis (Wilkinson 1998). A number of trials show the importance of an adequate intake of protein in the diet for maximum benefit of different kinds of training, but do not support recommendations for supplementation of protein in excess of what is supplied in a normal diet (Phillips 2004, Phillips 2005, Rankin 2004). It's well known that strength training leads to a change in body composition; the fat percent decreases while lean body mass increases (Cullinen 1998, Demling 2000, Nindl 2000, Yu 2005). In a few studies the effect of meal frequency has been investigated (Bujko 1997, Iwao 1996, Westerterp-Plantenga 2003, Young 1995), but there are few studies where the purpose has been to investigate to which degree meal frequency affects the change in body composition in coherence with strength training or what the optimum meal frequency for maximum protein synthesis is (Arnal 2000, Tipton 2001). It appears to be an increase in the availability of amino acids that stimulate increased protein synthesis, and that the synthesis will decrease in spite of a high level of amino acids maintained in the blood (Rennie 2002). It appears that a higher meal frequency will result in a higher anabolic response (Paddon-Jones 2005), but it still remains to be clarified which frequency of amino acid intake that is optimum for muscle growth. We can't discard the idea that a beneficial meal frequency has an effect on other tissues as well i.e. bone. With the increasing number of people working out in gyms, both to increase muscle mass and to reduce fat mass, it's desirable to be able to give recommendations regarding the number of meals to eat each day. The objective of this study was to investigate whether meal frequency is a significant factor in the change in body composition that occurs in a group of young men and women who are strength training while in positive energy balance.

2. Theory

2.1 Earlier studies

2.1.1 The effect of macronutrient intake

Roy & Tarnopolsky (1998) studied the effect of isoenergetic CHO (1 g/kg) and CHO/protein/fat (66% CHO, 23% protein, 11% fat) defined formula drinks and placebo given immediately and 1 hour after resistance exercise in 10 healthy young men. A bout of resistance exercise resulted in a significant decrease in muscle glycogen and consumption of an isoenergetic CHO or CHO/protein/fat formula drink resulted in similar rates of muscle glycogen resynthesis after resistance exercise. They hypothesised that total energy content and CHO content are important in the resynthesis of muscle glycogen. A few years later, Ivy et al (2002) suggested that a CHO-protein supplement is more effective for the rapid replenishment of muscle glycogen after exercise than a CHO supplement of equal CHO or caloric content. In resistance training the desire to stimulate maximum muscle protein synthesis still present researchers with a number of questions. Only small amounts of protein seems to be necessary for maximum increase in protein synthesis, and it appears that only EAA are needed, as amounts from 6g to 40g of EAA all gave maximum increase (Cuthbertson et al 2005, Volpi et al 2003, Børsheim 2002, Rasmussen et al 2000, Tipton et al 1999a, Tipton et al 1999b). Børsheim et al (2004) found that after resistance exercise, a mixture of whey protein, AA, and CHO stimulated muscle protein synthesis to a greater extent than isoenergetic CHO alone. Further, compared to previously reported findings, the addition of intact protein to an AA+ CHO mixture seems to extend the anabolic effect. Van Zant et al (2002) assigned subjects to groups consuming isoenergetic diets considered either high CHO/low fat or moderate CHO and fat in a randomly assigned crossover design. The findings indicated that varying dietary macronutrient content had no effect on exercise training or strength exercise performance in moderately trained (aerobic and strength) or sedentary males. Lemon et al (2002) suggests that protein type may be important owing to variable speeds of absorption and availability, differences in amino acid and peptide profiles, unique hormonal response, or positive effects on antioxidant defence. Not only type of protein, but also energy intake has an effect on muscle protein synthesis, and a positive energy balance has a positive effect on net nitrogen retention. An energy intake that is over the energy need will most likely lead to nitrogen retention of about 1-2mg per kcal (FAO/WHO/UNU 1985).

Table 2.1. The effect of macronutrient intake

	AUTHORS	YEAR	CONCLUSIONS
1	Tipton et al	1999b	Ingestion of oral essential amino acids results in a change from net muscle protein degradation to net muscle protein synthesis after heavy resistance exercise in humans similar to that seen when the amino acids were infused.
2	Tipton et al	1999a	Ingestion of a solution composed of carbohydrates to stimulate insulin release and a small amount of essential amino acids to increase amino acid availability for protein synthesis is an effective stimulator of muscle protein anabolism.
3	Rasmussen et al	2000	Essential amino acids with carbohydrates stimulate muscle protein anabolism by increasing muscle protein synthesis when ingested 1 or 3 h after resistance exercise.
4	Van Zant et al	2002	Varying dietary macronutrient content had no effect on exercise training or strength exercise performance in moderately trained (aerobic and strength) or sedentary males.
5	Børsheim	2002	NEAA are not necessary for stimulation of net muscle protein balance and there is a dose-dependent effect of EAA ingestion on muscle protein synthesis.
6	Volpi et al	2003	Essential amino acids are primarily responsible for the amino acid-induced stimulation of muscle protein anabolism in the elderly.
7	Børsheim et al	2004	After resistance exercise, a mixture of whey protein, AA, and CHO stimulated muscle protein synthesis to a greater extent than isoenergetic CHO alone
8	Cuthbertson et al	2005	The results demonstrate first, EAA stimulate muscle protein synthesis independently of increased insulin availability; second, in the elderly, a deficit in muscle protein synthesis in the basal state is unlikely, and third, the decreased sensitivity and responsiveness of muscle protein synthesis to EAA, associated with decrements in the expression and activation of components of anabolic signaling pathways, are probably major contributors to the failure of muscle maintenance in the elderly.

2.1.2 Timing of protein intake and type of protein

Short term studies

Levenhagen et al (2001) found that similar to carbohydrate homeostasis, after 60 min of moderate-intensity cycling exercise, early post exercise ingestion of a nutrient supplement enhances accretion of whole body and leg protein, suggesting a common mechanism of exercise-induced insulin action. Later, Bird et al (2006) examined chronic alteration of the acute hormonal response associated with liquid CHO and/or EAA ingestion on hormonal and muscular adaptations following resistance training. The results indicated that CHO + EAA ingestion enhances muscle anabolism following resistance training to a greater extent than either CHO or EAA consumed independently. Tipton et al (2001) found that the response of net muscle protein synthesis to consumption of an oral essential amino acid-carbohydrate supplement solution immediately before resistance exercise is greater than that when the solution is consumed after exercise. In a later trial, Tipton et al (2007) found that the response of net muscle protein balance to timing of intact protein ingestion does not respond as does that of the combination of free amino acids and carbohydrate. Dangin et al (2002), using a non-steady-state approach and intrinsically labelled milk protein fractions, whey protein and casein, showed that a slow digested dietary protein induced a greater gain in body protein than a fast one in young men, but in contrast to young subjects, a fast protein may be more beneficial than a slow one in elderly subjects, to limit body protein loss. Wilkinson et al (2007) examined the effect of consuming iso-nitrogenous, iso-energetic, and macronutrient-matched soy or milk beverages (18 g protein, 750 kJ) on protein kinetics and net muscle protein balance after resistance exercise in healthy young men. They concluded that milk-based proteins promote muscle protein accretion to a greater extent than do soy-based proteins when consumed after resistance exercise.

Table 2.2. Timing of protein and type of protein. Short term studies

	AUTHORS	YEAR	CONCLUSIONS
1	Levenhagen et al	2001	Similar to carbohydrate homeostasis, after 60 min of moderate-intensity cycling exercise, early post exercise ingestion of a nutrient supplement enhances accretion of whole body and leg protein, suggesting a common mechanism of exercise-induced insulin action.
2	Bird et al	2006	CHO + EAA ingestion enhances muscle anabolism following resistance training to a greater extent than either CHO or EAA consumed independently.
3	Tipton et al	2001	The response of net muscle protein synthesis to consumption of an oral essential amino acid-carbohydrate supplement solution immediately before resistance exercise is greater than that when the solution is consumed after exercise.
4	Tipton et al	2007	The response of net muscle protein balance to timing of intact protein ingestion does not respond as does that of the combination of free amino acids and carbohydrate.
5	Dangin et al	2002	A slow digested dietary protein induced a greater protein gain than a fast one in young men, but in contrast to young subjects, a fast protein may be more beneficial than a slow one in elderly subjects, to limit body protein loss.
6	Wilkinson et al	2007	Milk-based proteins promote muscle protein accretion to a greater extent than do soy-based proteins when consumed after resistance exercise.

Long term studies

Antonio et al (2000) studied the effects of 6 weeks of EAA supplementation on body composition and exercise performance in untrained women. Subjects were randomly assigned to a placebo (cellulose) or an EAA group. The conclusion was that in previously untrained individuals, the ingestion of EAAs combined with aerobic and heavy-resistance training for 6 weeks did not have a significant effect on body composition or muscular strength; however, aerobic muscular endurance increased significantly. In a later trial, Esmarck et al (2001) investigated the importance of immediate or delayed intake of an oral protein supplement upon muscle hypertrophy and strength over a period of resistance training in elderly males, and concluded that early intake of an oral protein supplement after resistance training is important for the development of hypertrophy in skeletal muscle of elderly men in response to resistance training. Williams et al (2001) included seven untrained participants who resistance trained on a leg extension machine for five days a week for 10 weeks. Alternate legs were trained on successive days, one leg each day. Subjects ingested either a supplement including 0.8 g glucose/kg and 0.2 g amino acids/kg, or placebo, on alternate training days immediately after training. Therefore the supplement was always ingested after training the same leg (supplement leg). The conclusion was that regular glucose/amino acid supplementation immediately after resistance exercise is unlikely to enhance the gain in muscle strength brought about by resistance training, but a trend towards a greater gain of muscle protein indicated that further investigation was needed. Chromiak et al (2004) performed a 10 weeks study with post exercise supplement where consumption of a recovery drink after strength training workouts promoted no greater gains in FFM compared with consumption of a CHO-only drink; however, a trend toward a greater increase in FFM in the supplement group suggests the need for longer-term studies. In a single-blind, randomised protocol by Cribb & Hayes (2006), resistance-trained males were matched for strength and placed into one of two groups; the PRE-POST group consumed a supplement (1 g x kg(-1) body weight) containing protein/creatine/glucose immediately before and after resistance exercise. The MOR-EVE group consumed the same dose of the same supplement in the morning and late evening. PRE-POST demonstrated a greater ($P < 0.05$) increase in lean body mass and 1RM strength. The changes in body composition were supported by a greater ($P < 0.05$) increase in cross sectional area of the type II fibres and contractile protein content. PRE-POST supplementation also resulted in higher muscle creatine and glycogen values after the training program ($P < 0.05$). Willoughby et al (2007) randomly assigned nineteen untrained males to supplement groups containing either 20 g protein or 20 g dextrose placebo ingested 1 h before and after exercise for a total of 40 g/d. The protein supplement resulted in greater increases in total body mass, fat-free mass, thigh mass, muscle strength, serum IGF-1, IGF-1 mRNA, MHC I and IIa expression, and myofibrillar protein. Recently, Beck et al (2007) examined the effects of a drink containing creatine, amino acids, and protein vs. a carbohydrate placebo on body composition, strength, muscular endurance, and anaerobic performance before and after 10 weeks of resistance training. The results suggested that the creatine-, amino acid-, and protein-containing drink provided no additional benefits when compared with carbohydrates alone for eliciting changes in body composition, strength, and muscular endurance after a 10-week resistance-training period. These results are in contrast to a large number of studies that have been published on creatine supplementation over the last decade. Many studies show that creatine supplementation in conjunction with resistance training augments gains in muscle strength and size (Racette 2003, Volek & Rawson 2004, Candow & Chilibeck 2007). Rankin et al (2004) conducted a trial where nineteen, untrained men (18-25 years) consumed either a milk or a carbohydrate-electrolyte drink immediately following each workout during a 10 week resistance training program. Milk tended to increase body weight and LBM ($p = 0.10$ and $p = 0.13$, respectively) compared to CHO, but the conclusion was that post-resistance exercise consumption of milk and CHO caused similar adaptations to resistance training. The positive effect of milk on muscle protein synthesis has later been supported when Hartman et al (2007) recruited 56 healthy young men who trained 5 d/wk for 12 wk on a rotating split-body resistance exercise program in a parallel 3-group longitudinal design. Subjects were randomly assigned to consume drinks immediately and again 1 h after exercise: fat-free milk, fat-free soy protein that was iso-energetic, iso-nitrogenous, and macronutrient ratio matched to milk or malt dextrin that was iso-energetic with milk and soy. The conclusion was that chronic post exercise consumption of milk promotes greater hypertrophy during the early stages of resistance training in novice weightlifters when compared with iso-energetic soy or carbohydrate consumption.

Table 2.3. Timing of protein and type of protein. Long term studies.

	AUTHORS	YEAR	CONCLUSIONS
1	Antonio et al	2000	In previously untrained individuals, the ingestion of EAAs combined with aerobic and heavy-resistance training for 6 weeks did not have a significant effect on body composition or muscular strength; however, aerobic muscular endurance increased significantly.
2	Esmarck et al	2001	Early intake of an oral protein supplement after resistance training is important for the development of hypertrophy in skeletal muscle of elderly men in response to resistance training.
3	Williams et al	2001	Regular glucose/amino acid supplementation immediately after resistance exercise is unlikely to enhance the gain in muscle strength brought about by resistance training.
4	Chromiak et al	2004	Consumption of a recovery drink after strength training workouts promoted no greater gains in FFM compared with consumption of a CHO-only drink; however, a trend toward a greater increase in FFM in the supplement group suggests the need for longer-term studies.
5	Cribb & Hayes	2006	Consuming a supplement containing protein/creatine/glucose immediately before and after resistance exercise demonstrated a greater increase in lean body mass and 1RM strength than when consuming the same dose of the same supplement in the morning and late evening.
6	Willoughby et al	2007	Ingestion of 20 g protein supplement 1 h before and after exercise resulted in greater increases in total body mass, fat-free mass, thigh mass, muscle strength, serum IGF-1, IGF-1 mRNA, MHC I and IIa expression, and myofibrillar protein than ingestion of 20 g dextrose placebo.
7	Beck et al	2007	A creatine-, amino acid-, and protein-containing drink provided no additional benefits when compared with carbohydrates alone for eliciting changes in body composition, strength, and muscular endurance after a 10-week resistance-training period.
8	Rankin et al	2004	Milk tended to increase body weight and LBM compared to CHO, but the conclusion was that post-resistance exercise consumption of milk and CHO caused similar adaptations to resistance training.
9	Hartman et al	2007	Chronic post exercise consumption of milk promotes greater hypertrophy during the early stages of resistance training in novice weightlifters when compared with iso-energetic soy or carbohydrate consumption.

Reviews

Lemon et al (2002) concluded in a review that recent data indicate that consuming a small meal of mixed macronutrient composition (or perhaps even a very small quantity of a few indispensable amino acids) immediately before or following strength exercise bouts can alter significantly net protein balance, resulting in greater gains in both muscle mass and strength than observed with training alone. Suzuki (2003) shows in a review the importance of high-glycemic carbohydrates consumed together with protein in enhancing the exercise-induced muscle formation relative to timing of intake. Insulin, which increases in blood after glycemic carbohydrate ingestion, seems to effectively stimulate protein synthesis and inhibit protein degradation right after exercise rather than later. Tipton & Wolfe (2004) concluded in a review that current literature suggests that it may be too simplistic to rely on recommendations of a particular amount of protein per day. Acute studies suggest that for any given amount of protein, the metabolic response is dependent on other factors, including the timing of ingestion in relation to exercise and/or other nutrients, the composition of ingested amino acids and the type of protein. A review by Phillips et al (2005) concluded that even when balanced quantities of total protein and energy are consumed that milk proteins are more effective in stimulating amino acid uptake and net protein deposition in skeletal muscle after resistance exercise than are hydrolysed soy proteins. Volek et al (2006) concluded in a review that attention to timing of nutrient ingestion, macronutrient quality, and dietary supplementation are important components of a nutritionally adequate and effective strength training diet for women.

2.1.3 Meal frequency

Short term studies

Westerterp-Plantenga, Kovacs & Melanson (2002) showed that healthy young men with a high habitual meal frequency showed lower 24 h energy intake, and a smaller difference in energy intake after macronutrient specific preloads, compared to those with a low habitual meal frequency, thus showing a more accurate energy intake regulation. This suggests that more frequent meals have a positive effect on weight regulation. Hulmi et al (2005) performed a study where 10 resistance-trained young men consumed breakfast 3 hours before a heavy strength training session and then either a 25 g of whey and caseinate proteins or a noncaloric placebo in a liquid form 30 min before a heavy strength training session in a crossover design separated by at least 7 d. A protein-carbohydrate supplement was consumed after the training session in both trials. The protein supplemented group obtained more anabolic muscular conditions than the non-supplemented group. A positive effect of frequent meals on muscle protein synthesis was supported when Paddon-Jones et al (2005) sought to determine whether ingestion of a between-meal supplement containing 30 g of CHO and 15 g of EAA altered the metabolic response to a nutritionally mixed meal in healthy, recreationally active male volunteers. Ingestion of a combination of COH/EAA supplements and meals resulted in a greater mixed muscle fractional synthetic rate than ingestion of the meals alone. The data indicate that CHO/EAA supplementation produces a greater anabolic effect than ingestion of intact protein but does not interfere with the normal metabolic response to a meal.

Table 2.4. Meal frequency. Short term studies.

	AUTHORS	YEAR	CONCLUSIONS
1	Westerterp-Plantenga, Kovacs & Melanson	2002	Healthy young men with a high habitual meal frequency showed lower 24 h energy intake, and a smaller difference in energy intake after macronutrient specific preloads, compared to those with a low habitual meal frequency, thus showing a more accurate energy intake regulation
2	Hulmi et al	2005	The protein supplemented group obtained more anabolic muscular conditions than the non-supplemented group
3	Paddon-Jones et al	2005	Ingestion of a combination of COH/EAA supplements and meals resulted in a greater mixed muscle fractional synthetic rate than ingestion of the meals alone. The data indicate that CHO/EAA supplementation produces a greater anabolic effect than ingestion of intact protein but does not interfere with the normal metabolic response to a meal.

Long term studies

Iwao et al (1996) investigated the effects of meal frequency on changes in body composition by food restriction on twelve boxers who were divided between a two meals (2M) per day group and a six meals (6M) per day group. Both groups ingested 5.02 MJ per day for 2 weeks. Although there was no difference in change of body weight by food restriction between the two groups, the decrease in LBM was significantly greater in the 2M group than in the 6M group. The 6M group had a tendency towards a larger loss of fat mass than the 2M group. The results suggest that the lower frequency of meal intake leads to a greater myoprotein catabolism even if the same diet is consumed. The positive effect of frequent meals on LBM was later supported when Bujko et al (1997) showed that after 3 weeks of feeding the mean growth rate of rats fed continuously was nearly 20% higher than rats fed the same amount in 2 meals. Rats fed 6 meals per day had a growth rate rather similar to the rats fed continuously. It is suggested that the difference is caused by metabolic restriction for an adequate utilisation of large meals. Therefore large meals are supposed to cause a waste of amino acids in the postprandial phase. In the "SWEDES"-study Vågstrand et al (2007) observed a few associations between eating habits and body fatness, but without any obvious patterns. The true differences in eating habits between lean and overweight adolescents are probably very small. A diet with less meal frequency can improve the health and extend the lifespan of laboratory animals, but its effect on humans has never been tested. Stote et al (2007) conducted a pilot study to establish the effects of a reduced-meal-frequency diet on health indicators in healthy, normal-weight adults. Subjects who completed the study maintained their body weight within 2 kg of their initial weight throughout the 6-month period. When consuming 1 meal per day, subjects had a significant increase in hunger; a significant modification of body composition, including reductions in fat mass. No significant difference in FFM was observed compared to the 3 meals per day group.

Table 2.5. Meal frequency. Long term studies.

	AUTHORS	YEAR	CONCLUSIONS
1	Iwao et al	1996	The decrease in LBM was significantly greater in the 2 meals per day group than in the 6 meals per day group. The 6 meals per day group had a tendency towards a larger loss of fat mass than the 2 meals per day group.
2	Bujko et al	1997	After 3 weeks of feeding the mean growth rate of rats fed continuously was nearly 20% higher than rats fed the same amount in 2 meals. Rats fed 6 meals per day had a growth rate rather similar to the rats fed continuously.
3	Stote et al	2007	Subjects who completed the study maintained their body weight within 2 kg of their initial weight throughout the 6-month period. When consuming 1 meal per day, subjects had a significant increase in hunger; a significant modification of body composition, including reductions in fat mass, but not in LBM.

Reviews

Bellisle, McDevitt & Prentice (1997) concluded that any effects of meal pattern on the regulation of body weight are likely to be mediated through effects on the food intake side of the energy balance equation. Studies using whole-body calorimetry and doubly-labelled water to assess total 24 h energy expenditure find no difference between nibbling and gorging, and there is no evidence that weight loss on hypoenergetic regimens is altered by meal frequency. Rennie & Tipton (2000) says in their review that resistance exercise causes little change in amino acid oxidation but probably depresses protein synthesis and elevates breakdown acutely. After exercise, protein synthesis rebounds for </=48 h, but breakdown remains elevated, and net positive balance is achieved only if amino acid availability is increased. Mosoni & Mirand (2003) said in a review that during young and adult ages, when food supply is liberal, subjects can adapt to various modes of protein feeding. However, during food restriction, protein anabolism is favored when the delivery of amino acids is evenly distributed over the day, either with frequent meals, or through the use of slowly absorbed proteins like casein.

2.1.4 Summary

A problem with both short-term trials mentioned on meal frequency is that the supplemented groups had a larger intake of both protein and total energy than the non-supplemented groups. It can’t be ruled out that it is the extra supplemented protein/energy and not the increased meal frequency that has caused an effect. Short-term studies only measure changes over the next few hours after training, while protein synthesis is elevated for up to 48 hours after a strength training session (Rennie & Tipton 2000, Phillips 2004, Phillips et al 1997). Recent data indicate that consuming a small meal of mixed macronutrient composition immediately before or following strength exercise bouts can alter significantly net protein balance, resulting in greater gains in both muscle mass and strength than observed with training alone. Trial results also suggest that milk proteins are more effective in stimulating amino acid uptake and net protein deposition in skeletal muscle after resistance exercise than are hydrolysed soy proteins. It could thus be hypothesised that a group consuming 6 meals per day, would gain more LBM than a group consuming 3 meals per day during twelve weeks of strength training, possibly with an additional effect when consuming milk containing meals both before and after training sessions. It appears that although effects of meal pattern on the regulation of body weight are likely to be mediated through effects on the food intake side of the energy balance equation, it could be easier to regulate daily energy intake according to energy expenditure when consuming 6 meals versus 3 meals per day and thus maintain a stable storage of body fat.

3. Methods

3.1 Subjects

3.1.1 Recruitment

Participants were recruited with posters placed at a number of training facilities used by students close to UIO; Domus Athletica, Blindern Athletica, Nydalen Athletica, Toppidrettssenteret, the strength room at NIH and also at the Norwegian Police University College, the Medical Faculty at UIO, Oslo University College and the strength room at Kringsjå student village. In this way we hoped to recruit people in the correct age group who would be able to train at NIH. All who reported their interest, received a letter of information (Appendix 1), and were invited to an information meeting at NIH where those who were eligible could register for the trial after a presentation of the trial (Appendix 2).

3.1.2 Study participants

Initially, 18 men and 5 women aged 20 to 36 with at least one year of previous strength training experience registered for the trial. They were paired according to gender and strength, determined by 1RM tests taken the week prior to week 1 of the trial. One person from each pair was then randomly assigned to either a 6M group or a 3M group, and the other person was assigned to the other group. From this first group of participants, only 8 men and 2 women completed the project, with the majority in the 6M group. A second group of men (n=15) and women (n=10) in the same age group were assigned to either the 6M group or the 3M group. These new participants were assigned to the 3M group and the 6M group in a block-randomised and counterbalanced fashion in order to get two similar groups according to both gender and strength. From this second group 8 men and 9 women completed the project. Over all 48 participants, 33 men and 15 women aged 20 to 36 with at least one year of previous strength training experience were assigned to the project. Twenty-seven participants completed the project, 12 in the 3M group; 7 men and 5 women, 15 in the 6M group; 9 men and 6 women. 21 failed to complete the project; 11 withdrew for personal reasons, 5 due to pain that the subjects linked to previous injuries, 2 due to injuries outside the project, 2 for lack of compliance to the training programme (one of these also admitted to earlier use of anabolic steroids) and 1 for lack of compliance to the diet. A description of participant average data in the 3M- and the 6M groups follows in table 3.1 and 3.2.

Table 3.1. Anthropometrical data for completing participants. (*=difference between groups, ± Std. Deviation)

Group	N	Men	Women	Age, years*	Height, cm	Weight, kg	BMI, kg/m^2
3M	12	7 (58%)	5 (42%)	29.4 ± 1.3	174.8 ±	72.3 ± 3.2	23.5 ± 0.6
6M	15	9 (60%)	6 (40%)	24.1 ± 0.8	176.2 ±	76.4 ± 5.0	24.4 ± 1.2

Table 3.2. Body composition of completing participants. (± Std. Deviation)

Group	Strength, kg	LBM, kg	Fat mass, kg	BMC, g
3M	345.0 ± 32.6	54.1 ± 3.0	15.1 ± 1.4	2934 ± 125
6M	345.0 ± 28.9	54.3 ± 3.5	18.2 ± 2.5	3001 ± 135

3.1.3 Inclusion criteria

-At least one year previous experience from strength training.

-Men and women, from 20 to 35 years old.

-Must be able to perform strength training four days per week at scheduled times at the Norwegian School of Sport Sciences.

-Participants must agree not to use supplements during the duration of the trial.

3.1.4 Exclusion criteria

-The use of ergogenous substances during the latest four weeks prior to the trial.

-Any earlier use of anabolic steroids or pro-hormones.

-More than one hour of additional endurance or strength training per week during the twelve weeks of the project.

3.2 Training

3.2.1 Training programme

The participants performed strength training four days per week at NIH, following a program (Appendix 3) composed by Per Egil Refsnes at NIF/OLT, designed to increase maximum strength and stimulate hypertrophy. It was also a criterion that the programme should not require more than 90 minutes of training each day. Day 1 and 3 of this 2-split programme had exercises for the legs and back, while day 2 and 4 had exercises for shoulders, chest and arms. Each muscle group had two training sessions each week. Mondays and Tuesdays were heavy sessions where the participants lifted weights that were so heavy that help was needed on the last one or two repetitions of each set. Heavy training sessions were all under guided supervision from trial leaders, as greater progress in muscle gain was expected with direct supervision (Mazzetti 2000). The heavy sessions were periodized, with heavier and shorter sets every four weeks; 8-12 repetitions the first four weeks, 6-10 repetitions the next four weeks and 4-8 repetitions the last four weeks. Thursdays and Fridays were light sessions with 10-12 repetitions per set. The participants should be able to do all repetitions alone. Light days were not supervised at all times, except at the beginning of the study. The participant kept records of how much they lifted each session to follow the progress. The goal was to increase the load each week. Two weeks prior to the study were used to familiarize the participants to the exercises. Only one hour of light endurance training was permitted in addition to the training in the study each week. The participants filled out a form each week, which described physical activity performed in addition to the training programme (Appendix 4).

3.2.2 Strength tests

Testing of maximum strength (1RM) was performed before the beginning of the twelve weeks of training (after 1 week of familiarization to the exercises), after 4 weeks, after 8 weeks and after all 12 weeks were completed. The 6 test exercises covered muscle groups from the whole body, and were squats in a smith machine, seated leg-curl, lying row with barbells, bench press, triceps pushdown and preacher curl. The exercises are described and illustrated under "Exercises". To avoid fatigue, the test was split in two following the training programme, testing squats in a smith machine, seated leg-curl and lying rowing with barbells on day 1, and testing bench press, triceps pushdown and preacher curl on day 2. Prior to testing, each participant had 10 minutes of light to moderate general warming up, either on a treadmill, a spinning bike, an elliptical trainer, a stepper or a rowing machine. The local warming up with the exercise that was tested consisted of 4 series, which successively increased the load while decreasing the number of repetitions. The first maximum lift was 5% lower than expected 1RM to ensure a successful lift. A 2-5% increase in load was then added for each new lift until the final attempt was failure to lift the load. There was 2-4 minutes rest between each test lift. A form was filled out for each participant each test round (Appendix 5). The load was calculated in % of expected 1RM. The first tests were based on sub maximum testing during the familiarization week and the following test were based on a progression of 1% strength increase per strength training session which has earlier been demonstrated in untrained individuals (Raastad 2005). We expected this would also fit our trial, because although our participants had at least 1 year of experience with strength training, none appeared highly trained at the beginning of the trial. We also monitored the participant's progress in strength during the 4 weeks between the tests and adjusted the expected test load for those who clearly had higher progress than expected.

3.2.3 Exercises

A description of all the exercises in the training programme, including pictures of some of the participants excecuting the test exercises.

Squats in a smith machine

With the bar in upper chest height, position the bar on the back of your shoulders and grasp the sides of the bar. Place your feet under the bar. Disengage the bar and descend until thighs are parallel to the floor. Extend knees and hips until legs are straight without locking the knees. Repeat.

Leg extensions

Sit on the machine with your back against the back support. Place the front of your lower legs under the lever. Adjust the seat until your knees are next to the rotation point of the lever. Grasp the handles on the side of the seat. Move the lever forward by extending your knees until your legs are straight. Return lever to original position without losing the tension in the muscles. Repeat.

Seated leg curl

Sit on the machine, lean against the back support. Place the thighs under the support just above the knees. Place the back of your lower legs on top of the padded lever. Adjust the seat until your knees are next to the rotation point of the lever. Tighten the belt and grasp the handles on the side of the seat. Pull the lever to the back of your thighs by flexing the knees. Return the lever until knees are straight, without relaxing the muscle. Repeat.

Calf raises in smith machine or sled

Position the bar in upper chest height and place a step block under the bar. Position the back of your shoulders under the bar and grasp the sides of the bar. Position your toes and the balls of your feet on the step block with the heels and arches of your feet extending outside the step block. Disengage the bar and stand erect by extending your knees and hips. Raise your heels by extending the ankles as high as possible. Lower your heels slowly until your calves are stretched. Repeat.

Or:

Lie down on your back with your seat towards the support. Place your feet on the platform, grasp the handles on the sides and extend your hips and knees. Position your toes and the balls of your feet on the lower portion of the platform with the heels and arches of your feet extending outside the platform. Push the sled by extending the ankles as far as possible. Return slowly until your calves are stretched. Repeat.

Weighted back extensions

Position your hip on the support pad and your feet on the platform under the support. Hold a plate or dumbbell toward your chest or behind the neck, or use no weight. Lower your upper body until your waist is fully flexed. Extend the waist until your torso is parallel to your legs. Repeat.

Lying row with barbells or Seated high row in machine

Lie chest down on an elevated bench. Grasp the barbell below with overhand grip. Pull the barbell up to your upper waist or lower chest. Return until your arms are extended and your shoulders are stretched forward. Repeat.

Or (alternative only in training, not test)

Adjust the seat to position your sternum against the support pad. Adjust the support pad so you are just able to reach the handles. Keeping upper arm horizontal, pull the lever with your elbows up and out to the sides until your upper arms are just beyond parallel. Return without relaxing the muscles and repeat.

Seated cable row

Sit on the bench with your feet on the platform with knees bent and grasp cable attachment. Pull cable attachment to your waist while straightening lower back. Pull shoulders back and push chest forward during contraction. Return until arms are extended, shoulders are stretched forward, and lower back is flexed forward. Repeat.

Weighted incline crunch

Place your legs in the support and lie on the decline board. Hold a plate on your chest with both hands or use no weight. Flex the waist to raise your upper torso from the bench. Return and repeat.

Lever seated crunch

Sit in machine with back against back support. Place your feet on the platform. Hold lever in front of the body. With the hips stationary, flex waist so the elbows travel downward. Return and repeat.

Dumbbell lateral raise

Grasp dumbbells with your arms hanging down the side of the body, bend slightly over at the hips with your knees bent. With your elbows slightly bent, raise upper arms to the sides until your elbows are shoulder height. Maintain elbows' height above or equal to wrists. Lower and repeat.

Seated shoulder press with dumbbells

Sit on an incline bench with the backrest almost straight up. Position dumbbells to each side of the shoulders with elbows below wrists. Press dumbbells until your arms are extended overhead without locking the elbow. Lower and repeat.

One arm rear dumbbell lateral raise

Grasp the dumbbell with one hand, letting your arm hang down with your elbow slightly bent. Bend your knees slightly and bend 30° over through the hips. Support your body towards a fixed object with the free arm. Raise your upper arm to the side until your elbow is shoulder height. Lower and repeat. Change arms and repeat.

Barbell bench press

Lie down on the bench. Dismount the barbell from the rack. Keep your head, shoulders and buttocks in contact with the bench and your feet still on the floor. Lower the weight to your upper chest. Press the bar until your arms are extended without locking your elbows. Repeat.

Dumbbell incline chest press

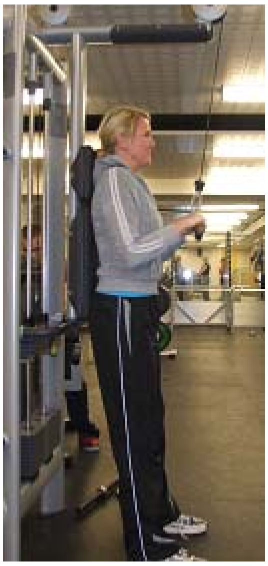
Position the incline bench with a 45° angle on the backrest. Sit down on the bench with the dumbbells resting on your lower thighs. Kick the weights to your shoulders and lie back. Position the dumbbells to the sides of your upper chest with your elbows under the dumbbells. Press the dumbbells up with your elbows to the sides until your arms are extended, without locking the elbows. Lower the dumbbells to the sides of your upper chest. Repeat.

Incline dumbbell flies

Grasp two dumbbells. Lie down on an incline bench with a 30° angle on the backrest towards the floor. Support the dumbbells above the chest with your arms fixed in a slightly bent position. Rotate your hands so that your palms face each other. Lower the dumbbells to the sides until your chest muscles are stretched. Keep your elbows fixed. Bring dumbbells together in an opposite motion until the dumbbells are nearly together. Repeat.

Triceps pushdown

Stand with your back towards the back support. Grasp the cable attachment with an overhand narrow grip. Position your elbows to your side. Extend your arms down without locking the elbows. Keep movement only in the elbow joints and forearms. Return until your forearms are close to the upper arms. Repeat.



French press

Lie on a bench with a narrow overhand grip on the barbell. Position the barbell over your forehead with your arms extended. Lower the barbell to your forehead by bending your elbows. Extend your arms with movement only in the elbow joints and forearms. Repeat.

Preacher curl

Sit on a curl bench placing the back of your arms on the pad. The seat should be adjusted to allow your armpit to rest near the top of the pad. Grasp the cable attachment with an underhand grip. Raise the handle until your elbows are fully flexed with the back of your upper arms remaining on the pad. Lower the handles until your arms are fully extended without relaxing the muscles. Repeat.

Dumbbell incline curl

Grasp two dumbbells. Sit down on an incline bench with a 45° angle on the backrest. With your arms hanging down straight, face palms inwards. Raise one dumbbell and rotate your forearm until the forearm is vertical and the palm faces shoulder. Lower the dumbbell to the original position and repeat with the opposite arm. Continue to alternate between right and left sides.

3.3 Activity registration

A 2-days self-reported activity registration (Appendix 6) was performed to establish the usual activity level of each participant. Each 30 minutes on a Wednesday and a Thursday, they noted their activity, which was multiplied with an activity factor from 1 for sleeping to 6.6 for exercise. The activity factors were taken from Annex 5, Gross energy expenditure in specified activities (FAO/WHO/UNU 1985), and activities not listed there were given an estimated value. Cunningham's prediction equation has demonstrated good calculated RMR values for both active men and women (Thompson, J & Manore, MM 1996), and was used to calculate the individual energy requirements by multiplying with the average activity factor for each participant. Information of what kind of earlier physical activity the participants had been performing was also collected (Appendix 7). In case of lacking progress in individual participants, these data could be used to see if this could be due to a reduction in physical activity when joining the trial.

3.4 Diets

3.4.1 4-days weighed registration

Each participant went through a 4-days weighed registration prior to the study, Wednesday through Saturday (Appendix 8). These data were used to compose an individual diet for each participant, using foodstuffs palatable for the individual and meeting guidelines for dietary intake set by the project. Each participant was lent a kitchen scale with accuracy of 1g when they received written guidelines and personal guidance by one of the project leaders on how to execute the registration and how to fill out the form. We estimated a 10% underreporting and under eating, as validation using biomarkers has revealed evidence that dietary records underestimate true dietary intake (Black 1993).

3.4.2 Dietary intervention

The participants were given examples of diets based on our guidelines (Appendix 9) containing energy, protein and carbohydrates according to recommendations for athletes from the Norwegian directorate for health and social affairs; Mat og prestasjon, Kostholdsanbefalinger for idrettsutøvere; Carbohydrates: 5-7g/kg/day (sugar < 10 E%), protein: 1,4-1,8g/kg/day, fat: 20 <E%< 30 (saturated fat < 10 E%), dietary fibre: 30-35g/day. No or moderate use of alcohol was recommended. All were given a diet with 1260kJ/day in addition to their calculated needs (based on activity registration and 4-days weighed registration) to achieve an energy surplus and give the right conditions for muscle gain. For our subjects, this should result in nitrogen retention leading to about 750-1500 grams of muscle gain in the twelve weeks duration of the trial due to energy surplus alone. In addition to follow energy-, protein- and carbohydrate recommendations, the participants were instructed to eat five servings of fruits and vegetables and one serving of fat fish or cod-oil each day. All micronutrients were covered according to national guidelines. Each participant was guided in a personal consultation regarding how to divide the day's nutrient intake on three or six meals respectively. TINE supplied the participants with yoghurt, so all but one woman with milk allergy had a daily intake of yoghurt. The 6M group was instructed to eat a recovery meal containing 0,1g protein/kg BW and 1g CHO/kg BW after training (Burke 2006). A comparison of energy-, protein and carbohydrate intake from the 4-days weighed registrations, the suggested diets and the 24-hour recalls follow in table 2.

3.4.3 24-hour recall

To control that the participants were following their assigned meal frequency, selecting proper foodstuffs and getting the right amount of protein, carbohydrate and energy, four unannounced 24-hour recalls (Appendix 10) were taken throughout the study. All the interviews were performed on Thursdays to avoid registering any variation in the diet due to weekday variations. These data have been used to calculate intake of energy, protein, carbohydrates, fat and micronutrients.

Table 3.3. Energy, protein and CHO intake. (± Std. Deviation)

Nutrient	Group	4-days weighed registration	24-hour recall	Menu
Energy,	3M	163 ± 47	154 ± 22	171 ± 12
kJ/kg BW/day	6M	135 ± 25	146 ± 27	166 ± 15
Protein,	3M	1.7 ± 0.5	2.0 ± 0.3	2.0 ± 0.2
g/kg BW/day	6M	1.5 ± 0.4	1.7 ± 0.4	1.9 ± 0.1
CHO,	3M	4.6 ± 1.3	4.5 ± 0.8	5.5 ± 0.5
g/kg BW/day	6M	3.9 ± 0.8	4.5 ± 0.8	5.5 ± 0.5

3.5 Body weight and composition

3.5.1 Weighing

Weighing of the participants took place every Tuesday before the training session in a dry t-shirt and underwear. The results were noted in a form (Appendix 11) by one of the project leaders. The same scale was used each time, and was calibrated every week using 60kg of Eleiko weights. Project leader noted the weight, and participants who were lacking weight gain were instructed to increase their daily food intake. They were given advice on which foodstuffs they could add to their existing diet, which foodstuffs they should increase and decrease their intake of and which meal that seemed the easiest to adjust in a way that would optimise their nutritional intake.

3.5.2 MRI

MRI to measure cross-sectional area of both thighs and dominant upper arm took place before and after the trial at Centrum Røntgeninstitutt, Oslo, Norway. Therese Fostervold Mathisen used these results in her paper about the effect of meal frequency on strength and muscle gain. MRI is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body, and is based on the principles of NMR, a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules. The human body is primarily fat and water. Fat and water have many hydrogen atoms, which make the human body approximately 63% hydrogen atoms. Hydrogen nuclei have an NMR signal. For these reasons MRI primarily images the NMR signal from the hydrogen nuclei.

3.5.3 DEXA

DEXA of the whole body was performed at Volvat Medical Centre, Oslo, Norway, before, after six weeks of training and after the study. DEXA scans are primarily used as screening and diagnostic tests for osteoporosis. DEXA provides a 3-compartment model of body density, i.e., bone mass, LBM, FM, and is also useful in determining body composition. DEXA uses small doses of X-rays, about 1/30 of the radiation dose used in a standard chest X-ray. For the test, a patient lies down on an examining table, and the scanner rapidly directs x-ray energy from two different sources towards the bone being examined in an alternating fashion at a set frequency. The differential attenuation of the two energies is used to estimate the bone mineral content and the soft tissue composition.

3.6 Statistical analysis

All tests were performed with SPSS version 13.0 for windows. Testing with Kolmogorov-Smirnov test and Shapiro-Wilk tests showed that the data had a normal distribution. Testing of changes in body composition was performed with t-tests. Effects of meal frequency were tested with multiple regression analysis. We have chosen $p \leq 0.05$ as level of significance.

3.7 Ethics

The National Committees for Research Ethics in Norway approved the trial after including both genders in the project. All participants signed a declaration of willingness to participate and were informed that they could withdraw from the trial at any time for any reason.

3.8 Financing

Supported by Tine BA, Oslo, Norway with Nkr; 55360,- and yoghurt for the participants and by the Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway with Nkr; 5000,-.

4. Results

Lean Body Mass

The 3M group had a strong tendency towards greater gain in LBM than the 6M group after twelve weeks of strength training, 1.71% (-0.18, 3.59), p=0.075. The 3M group had an increase in total body LBM of 5.45%, (3.43, 7.46), p<0.001 and the 6M group had an increase in total body LBM of 3.86%, (3.07, 4.66), p<0.001.

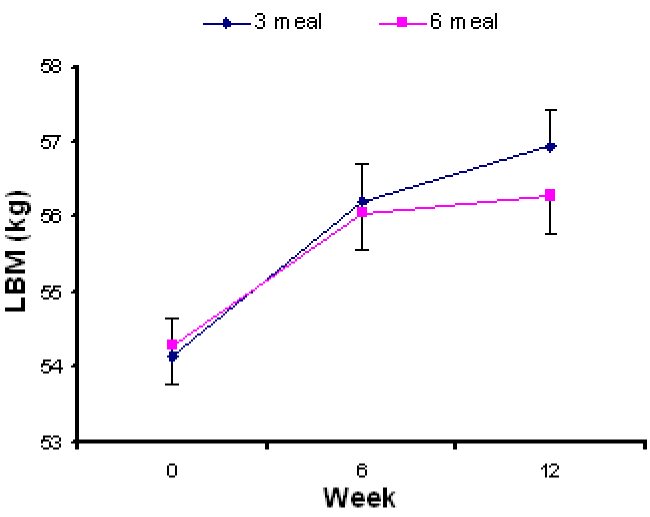


Figure 4.1. LBM

After linear regression analysis the difference was significant when adjusted for gender and energy intake (p=0.045), when adjusted for gender and protein intake (p=0.027), and when adjusted for gender, protein intake, carbohydrate intake and fat intake*(p=0.011). (*: Fat intake in g/kg body weight/day showed significance, p=0.030, Table 4.2) No significant differences in regional changes in LBM were observed, although there was a tendency towards a greater gain in the 3M group. The 3M group had an increase in LBM in the arms of 9.74%, (6.47, 13.01), p<0.001 and the 6M group had an increase in LBM in the arms of 6.05%, (2.64, 9.46), p<0.001, no significant difference between the groups, 3.12% (-0.94, 8.32), p=0.114. The 3M group had an increase in LBM in the legs of 5.55%, (2.99, 8.11), p=0.001 and the 6M group had an increase in LBM in the legs of 4.15%, (1.83, 6.47), p=0.002, no significant difference between the groups, 2.09% (-0.90, 5.07), p=0.162. The 3M group had an increase in LBM in the trunk of 4.87%, (2.23, 7.51), p=0.002, and the 6M group had an increase in LBM in the trunk of 3.79%, (2.74, 4.83), p<0.001, no significant difference between the groups, 1.01% (-1.49, 3.52), p=0.412.

Table 4.1. Effect of meal frequency on change in LBM adjusted for gender and energy intake. (* = significant, p<0,05)

	Unadjusted			Adjusted		
Variable	effect	95% CI	p	effect	95% CI	p
Meal frequency	-1.58	{-3.43 , 0.26}	0.090	-1.87	{-3.70 , -0,05}	0.045*
Gender	1.42	{-0.48 , 3.31}	0.136	1.31	{-0.54 , 3,15}	0.156
Energy, kJ/kg/day, recall	-0.02	{-0.06 , 0.02}	0.251	-0.03	{-0.06 , 0,01}	0.186

Table 4.2. Effect of meal frequency on change in LBM adjusted for gender, protein-, carbohydrate-, and fat-intake. (* = significant, p<0,05)

	Unadjusted			Adjusted		
Variable	effect	95% KI	p	effect	95% KI	p
Meal frequency	-1.58	{-3.43 , 0,26}	0.090	-2.48	{-4.34 , -0.63}	0.011*
Gender	1.42	{-0.48 , 3,31}	0.136	1.11	{-0.62 , 2.83}	0.198
Protein, g/kg/day, recall	-0.80	{-3.61 , 2,02}	0.566	-1.54	{-4.51 , 1.43}	0.294
Carbohydrate, g/kg/day, recall	-0.22	{-1.53 , 1,09]	0.734	1.10	{-0.32 , 2.51}	0.121
Fat, g/kg/day, recall	-3.24	{-6.57 , 0,09}	0.056	-4.36	{-8.26 , -0.46}	0.030*

Table 4.3. Effect of meal frequency on change in LBM adjusted for gender and protein intake. (* = significant, p<0,05)

	Unadjusted			Adjusted		
Variable	effect	95% KI	p	effect	95% KI	p
Meal frequency	-1.58	{-3.43 , 0.26}	0.090	-2.21	{-4.15 , -0.27}	0.027*
Gender	1.42	{-0.48 , 3.31}	0.136	1.44	{-0.37 , 3.25}	0.113
Protein, g/kg/day, recall	-0.80	{-3.61 , 2.02}	0.566	-1.93	{-4.66 , 0.80}	0.157

Weight

The 3M group had a weight increase of 5.23%, (3.34, 7.10), p<0.001 and the 6M group had a weight increase of 2.35%, (0.87, 3.84), p=0.004. There was a significant difference between the groups 2.87%, (0.62, 5.12), p=0.014.

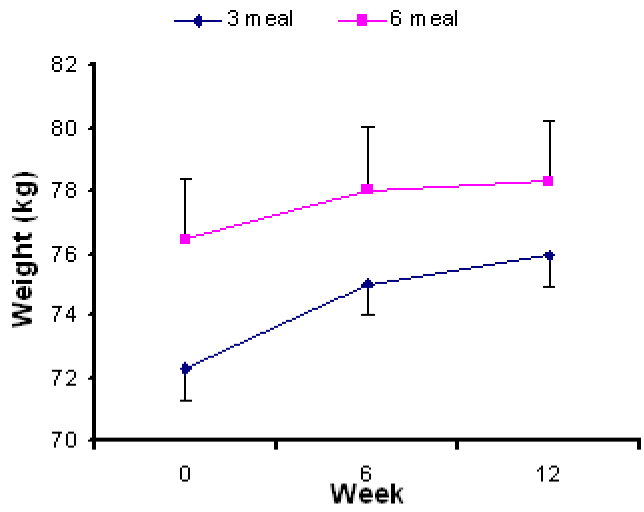


Figure 4.2. Body weight

Bone Mineral Density

The 6M group had an increase in BMD of the spine of 2.16%, (0.25, 4.07), p=0.029 and the 3M group had a tendency towards an increase in BMD of the spine of 2.51%, (-0.19, 5.21), p=0.065, no difference between the groups 0.35%, (-2.69, 3.40), p=0.814. Both groups analysed together showed an increase in BMD of the spine of 2.31%, (0.83, 3.79), p=0.003.

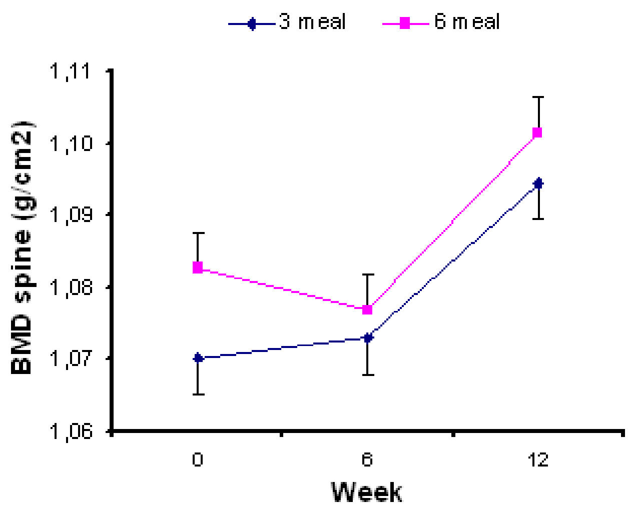


Figure 4.3. BMD of the spine

Fat Mass

There were no significant differences in change in fat mass (FM) between the groups, but a tendency towards a greater gain in the three meal group, 7.33% (-5.23, 19.90), p=0.241. Regional differences: FM-arms: 2.78% (-22.03, 27.58), p=0.820. FM-legs: 7.33% (-3.25, 17.90), p=0.166. FM-trunk: 8.23% (-6.72, 23.18), p=0.268.

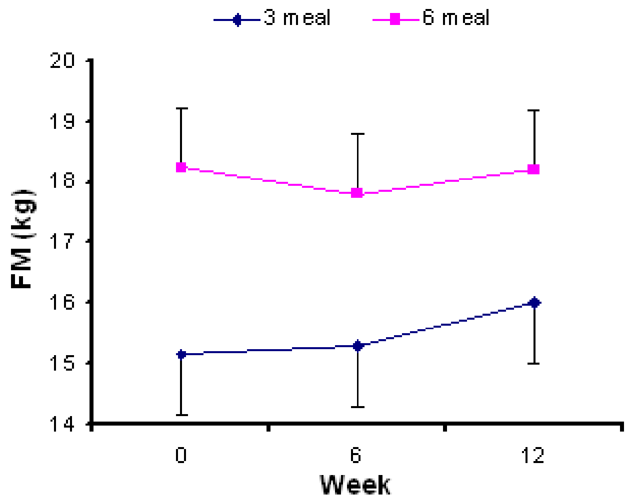


Figure 4.4. Fat mass

Strength

The 3M group had a larger strength increase in Barbell Bench Press (p=0,006), Triceps Pushdown (p=0,011) and upper body exercises average increase (p=0,017). The 3M group had a significantly higher average increase for all six exercises than the 6M group (p=0,035). There were no significant differences in strength increase between the groups for the lower body.

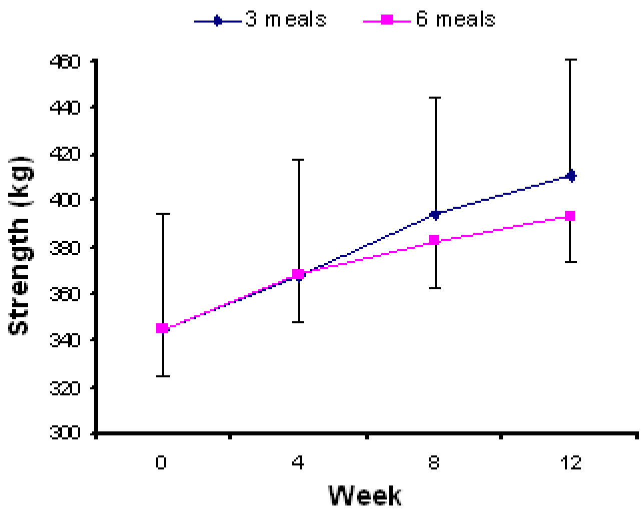


Figure 4.5. Whole body strength

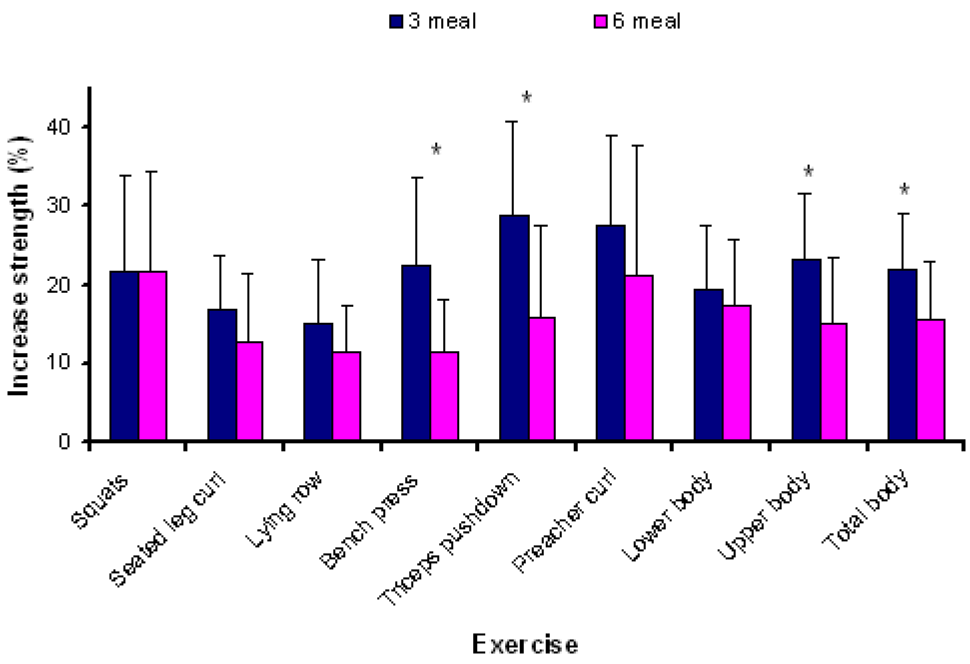


Figure 4.6. Strength increases. (* = Significant difference between groups, p<0.05)

Age and gender

Testing for the effect of the participants' age, showed no significance for any changes in body composition or strength. The females had a tendency towards a larger gain in LBM than the males, (p=0,118).

5. Discussion

The 3M group had a greater gain in LBM than the 6M group after twelve weeks of strength training. There were no significant differences in change in fat mass between the groups, but a tendency towards a greater gain in the 3M group. The 3M group had a larger weight gain than the 6M group. The 3M group also had a larger strength gain in bench press and triceps pushdown and a larger strength gain for the upper body and total body than the 6M group. The participants had a 2.31% gain in bone mineral density of the spine during the twelve weeks of strength training, but there were no differences between the groups.

5.1 Subjects

One woman who was 36 years old was included in the trial despite that she was over the age limit. Due to the low number of women who registered for the first part of the trial, we thought that it would be better to have one woman slightly over the age limit than to have one woman less in the trial. The age limit of 35 years that was set by us prior to the trial does not represent any limitation in the ability to gain muscle mass during strength training anyway. The higher dropout from the 3M group does not appear to have any connection to the meal frequency itself. Because of the close contact between the participants and the trial leaders, a bond of trust developed. The participants appeared to be truthful about the information they gave regarding to their diets and training, even when it resulted in exclusion from the trial.

5.2 Dietary intervention

5.2.1 4-days weighed registration

A minimum of 7 days is considered necessary to assess the energy and protein intakes of individuals to within a 10% standard error (Bingham 1987). A shorter timescale may be adequate in people with very stable eating habits, and we believe that our students were in that category. A longer period would possibly lead to a lower compliance and accuracy and a higher drop-out rate, because the participants may grow tired of the recording procedure, as it requires a lot of effort (Daniels 1984, Krall & Dwyer 1987). A registration period of 3-4 days, which includes both weekdays and weekends, gave a good assessment of macronutrients while the workload on the participants was acceptable. In our case the weighed registration served only as a database from were we composed the individual diets as well as giving us an overview of eating habits. Whether there was underreporting, adjustment of the diet to make recording easier or other inaccuracies was not of crucial importance. Table 2 suggested that our participants didn't underreport in their weighed registration, as the 24-hour recalls showed that both groups had energy intakes that were lower than the suggested menus while they were still gaining weight throughout the trial. This was not surprising as they proved to be highly motivated to follow all guidelines set by the trial, and in addition most of them were students with strict daily routines.

5.2.2 Dietary intervention

The participants seemed happy with the diets they were given as examples of what to eat, and there were only a few adjustments of the individual diets during the trial. One explanation could be that all diets were matched to each participant's taste and preference of foodstuffs based on the weighed registration. Another reason could be that all participants were given individual consultations to discuss food choices in their menus. In addition, the participants seemed highly motivated to do the best they could throughout the trial. Given the fact that our participants trained much less than athletes, special considerations to the diet outside the general recommendations should not have been necessary, but a diet based on recommendations for athletes may have contributed psychologically to better compliance to the diets. Although the participants were given examples of diets based on recommendations for athletes doing strength training, they were in practice the same as the recommendations made for the general population by the Norwegian directorate for health and social affairs (Becker 2004, Sosial- og helsedirektoratet 2003). Since the participants gained weight throughout the trial, they were more likely to be in positive energy balance than if they were losing weight, and they were eating protein according to the recommendations, thus suggesting that the right conditions for muscle gain were present (Phillips 2004). But body weight is not a reliable indicator of either energy or macronutrient balance in athletes, because protein and glycogen stores are associated with much more body water than are in fat stores. A weight gain due to small increases in protein or glycogen stores can counterbalance the weight loss due to larger reductions in fat energy stores during negative energy balance (Loucks 2004). However, an athlete's aim is often to reduce fat mass while increasing fat free mass and glycogen stores. Participants who did not gain weight were told to eat more and given dietary consultation if they felt that it was necessary. In this trial the 6M group had a small reduction in fat mass after 6 weeks, but the much larger increase in LBM shows that they still were in positive energy balance. Table 3.3 showed that they were closer to their recommended intake of nutrients in the 24-hour recalls during the trial than in the 4-days weighed registration prior to the trial. Together this suggested that dietary interventions have effects on the food intake of young people who participate in training projects, but because there were no follow up after the end of the project, little can be said about the long-term effects.

5.2.3 24-hour recall

It could be argued that four 24-hour recalls are not enough to give a good enough picture of how well the participants followed their diets. But as we were interested in the meal frequency, we believed that it showed us that the participants were following their meal frequency very well, as there was very few recall interviews that showed any irregularities. The recalls showed that the participants had a large enough total intake of protein. However, some of the meals in the 6M group had less protein than suggested by the calculated menus. Could it be that more frequent meals also require a closer attention to the protein content of each meal? A trial by Cuthbertson et al (2005) indicates that maximum stimulation of muscle protein synthesis is obtained with an intake of 10g of EAA in each meal. This suggests that the potential benefit of frequent meals may have been reduced in some cases because not all meals stimulated muscle protein synthesis maximally. However, this can not explain why we observed less increase in LBM in the 6M groups than in the 3M groups because the 6M group still had at least 4-5 meals per day with the recommended intake of EAA. Even if the energy intake appeared to be lower than suggested in the menu, the participants' weight increase throughout the project indicates that they ate enough. As mentioned, this could be because the participants didn't underreport in their weighed registrations. And as mentioned, the participants appeared to answer to the best of their ability in the interviews. The same person performed the interviews each time to avoid any interviewer bias. Only one person handled the data collected to avoid different interpretations of reported foods when punching them into the data programme. In one of the multiple regression analysis, fat intake was a significant factor together with meal frequency. Could it be that through evolution, choosing fat-dense foodstuffs has favoured survival, and that there are mechanisms between fat-intake and muscle protein synthesis that have not yet been investigated?

5.2.4 Training and strength tests

Participants had the same training programme and testing, the same supervisors, the same training schedule and the same training location, and hence, they were left no room for different results due to the training programme. The test exercises covered all parts of the body, and gave a good picture of overall strength gain. The same project leader tested each participant each time at the same time of day, which minimized risk of variation due to different test leaders and variation due to diurnal strength variations.

5.2.5 Analysis of body composition

People performing strength training are mainly interested in gaining LBM, and to some extent to reduce fat mass. Heavy resistance training is associated with increased body weight, lean body mass, and muscle cross-sectional area (Tesch 1988). Changes in LBM are analysed with methods such as DEXA, MRI and hydrostatic weighing. In this trial, DEXA and MRI have been used. DEXA analyses were also used to investigate changes in fat mass and BMD.

DEXA

Because DEXA calculates BMD using area, it is not an accurate measurement of true bone mineral density, which is mass divided by a volume. In this project however, I only looked at the changes in BMD, assuming that any error due to these inaccuracies would be similar for every measurement. Tests performed with DEXA are very susceptible to operator error, and error between machines can introduce errors large enough to wipe out the sensitivity of the measurements, so the same technician and the same machine was used in all measurements, minimizing any operator error and machine variability. One important confounding variable is bone size. DEXA has been shown to overestimate the bone mineral density of taller subjects and underestimate the bone mineral density of smaller subjects. This error is due to the way in which DEXA calculates BMD. In DEXA, bone mineral content (measured as the attenuation of the X-ray by the bones being scanned) is divided by the area (also measured by the machine) of the site being scanned. Again we assumed that we could disregard this confounding variable, as we were only looking at changes and the participants' bone size would be the same size for each measurement. DEXA measurements are based in part on the assumption that the hydration of fat-free mass remains constant at 73%. Hydration, however, can vary from 67%–85%. Other assumptions used to derive body composition estimates are considered proprietary by DEXA manufacturers. DEXA measurements of bone mass are thought to have a precision error of 1%–3%. Given the slow rate of change in bone mineral density in postmenopausal women treated for osteoporosis, it is likely that DEXA scans would only be able to detect a significant change in bone mineral density in the typical patients after one-two years of therapy (Lenchik 2002). However, exercise-induced mechanical loading can have potent effects on skeletal form and health (Zernicke 2006), and strength-training projects have shown an increase in BMD of the spine of 1%-3% after only twelve weeks of training (Raastad 2007), indicating a much quicker remodelling of the bone with larger stress on the bone due to weight training. Since all analyses were based on changes in groups and not individual changes, the results can be considered valid despite precision error and slow rate of bone remodelling. Of course, changes in body composition are anticipated to be larger and more rapid than changes in bone mineral density, and precision errors in DEXA scan become less critical in interpreting results on changes in FM and LBM. Many studies have used DEXA to monitor changes in body composition, and the precision is similar to that estimated for DEXA measurements of bone mineral density (Albanese 2003). In this trial the DEXA results concerning LBM showed the same pattern as the MRI and strength tests, and this supports the validity of the DEXA results.

MRI

Results from MRI showed a greater increase in muscle cross sectional area in both groups, with a significantly higher increase in the upper arm for the 3M group than the 6M group (Fostervold, 2006). This shows the same pattern as the other tests.

Gender

Gender had no effect on differences between the groups, as the groups had similar combination of men and women. Although the 6M group had a higher average age than the 3M group, this difference gave no significant effect on the results. It appears that it was meal frequency that had an effect on the different gains in LBM and strength between the groups.

Lean Body Mass

Although 3 meals per day resulted in a larger gain in LBM than 6 meals per day in this trial, it is important to keep in mind that our participants had a relatively small weekly training load. Increasing the weekly training load would also require a larger intake of food to get enough energy, carbohydrate and protein. This would probably not have been possible while still eating only three meals per day, as our participants were struggling to eat the already large meals. But the results suggests that it could be more beneficial to eat few and larger meals than many smaller meals to obtain maximum gain in LBM. One possible explanation for this is that the larger meals give a larger increase in postprandial plasma EAA, resulting in larger stimuli for protein synthesis and muscle gain. A trial performed on elderly women showed larger muscle protein synthesis with an intake of three larger meals with 80% of the protein in the middle meal than with four smaller meals where the protein was spread evenly between the meals (Arnal 1999). A trial by Cuthbertson et al (2005) suggest that maximum stimulation of muscle protein synthesis is obtained with an intake of 10g of EAA and 30g of CHO. Our trial suggests that other mechanisms than age related changes in metabolism might be involved, as there was no significant difference in age between the groups.

Bone Mineral Density

Meal frequency had no effect on gain in BMD, but strength training gave a large increase in BMD of the spine. This can be explained by the increased load on the spine compared to earlier activities in these groups, as none of the participants had trained squats this hard earlier. An increase of about 2% was expected as this is supported by results from other trials at NIH (Raastad 2007). A review of muscle training for bone strength shows a 2-5% gain in BMD and BMC per year (Suominen 2006). Sinaki et al (1993) demonstrated that osteoporotic women had significantly lower back extensor strength than the normal women, and this confirmed an earlier review which concluded that there was a significant correlation between muscle strength and bone mineral density (Sinaki 1989).

Fat Mass

Although the large variations in FM within and between the groups resulted in no significant differences between the groups, the 3M group had a mean gain in FM of 9,2% while the 6M group only had a mean gain of 1,9%. Looking at the median values, the 3M group had a 4,5% gain, while the 6M group had a 2,2% reduction in FM. Perhaps these results can be included in a meta analysis to show that many smaller meals are beneficial when gain in FM is not desired. Iwao (1996) had the same tendency with larger absolute difference in FM than in LBM between the groups, but still significant only for LBM. Recent epidemiological studies, mostly carried out in France, have provided evidence on the beneficial effects of a fourth meal for those individuals who habitually choose this pattern. Supported by metabolic data, these findings have now been supported by experimental studies. The "goûter", commonly eaten in the afternoon in France by most children and many adults, has the biological characteristics of a meal because it is eaten in response to hunger. Suppressing the "goûter" in "habitual fourth meal eaters" soon leads to an increase in Body Mass Index (BMI) (Louis-Sylvestre 2003). Healthy young men with a high habitual meal frequency showed lower 24 h energy intake, and a smaller difference in energy intake after macronutrient specific preloads, compared to those with a low habitual meal frequency, thus showing a more accurate energy intake regulation (Westerterp-Plantenga, Kovacs & Melanson 2002). DEXA indicates that the 6M group had a reduction in fat mass after six weeks of training, suggesting a possibility that the 6M group had been in negative energy balance part of the duration of the trial. But with the large gain in LBM versus only a small reduction in fat mass, it is more likely that the 6M group also had a positive energy balance throughout the duration of the trial.

Strength

Increase in strength shows the same pattern as increase in LBM measured by DEXA and increase in muscle cross sectional area measured by MRI. It is not surprising that these three measurements are linked together quantitatively and qualitatively as they in theory measure the same body component. This suggests that our methods are valid. Earlier trials have also recorded correlation between cross sectional area of a muscle and strength (Maughan 1983, Davies 1988).

6. Conclusion

In this study, three meals per day resulted in larger gain in LBM from strength training when in positive energy balance than six meals per day over a period of twelve weeks. The larger gain in LBM by the 3M group determined by DEXA was supported by the larger increase in strength measured with 1RM tests and the larger increase in muscle cross sectional area determined by MRI, suggesting both a quantitative and a qualitative effect of meal frequency. The reason why we draw opposite conclusions from short-term studies needs further investigation. More long-term studies are needed to determine the best meal frequency for ultimate gain in LBM from strength training. Larger groups may be needed to determine an effect of meal frequency on FM. The changes in FM had large variations within and between the groups, making it difficult to draw any conclusions. An environment where the participants' food intake and other activity are better controlled would be preferable. To perform this trial in a prison, where all activity and nutrient intake could be controlled strictly, could be a scientifically valuable contribution to this field of research. Voluntary participation from the prisoners would be necessary for ethical as well as methodical reasons.

References

Albanese CV, Diessel E, Genant HK. Clinical applications of body composition measurements using DXA. J Clin Densitom. 6(2):75-85, 2003.

Antonio J, Sanders MS, Ehler LA, Uelmen J, Raether JB, Stout JR. Effects of exercise training and amino-acid supplementation on body composition and physical performance in untrained women. Nutrition. Nov-Dec;16(11-12):1043-6, 2000.

Arnal MA, Mosoni L, Boirie Y, Houlier ML, Morin L, Verdier E, Ritz P, Antoine JM, Prugnaud J, Beaufrère B, Patureau MP. Protein pulse feeding improves protein retention in elderly women. Am J Clin Nutr 69: 1202-1208, 1999.

Arnal MA, Mosoni L, Boirie Y, Houlier ML, Morin L, Verdier E, Ritz P, Antoine JM, Prugnaud J, Beaufrère B, Patureau MP. Protein feeding pattern does not affect protein retention in young women. J Nutr 130: 1700-1704, 2000.

Beck TW, Housh TJ, Johnson GO, Coburn JW, Malek MH, Cramer JT. Effects of a drink containing creatine, amino acids, and protein combined with ten weeks of resistance training on body composition, strength, and anaerobic performance. J Strength Cond Res. Feb;21(1):100-4, 2007.

Becker W, Lyhne N, Pedersen AN, Aro A, Fogelholm M, Þhorsdottir I, Alexander J, Anderssen SA, Meltzer HM, Pedersen JI. Nordic Nutrition Recommendations 2004 – integrating nutrition and physical activity. Scandinavian Journal of Nutrition. 48 (4): 178-187, 2004.

Bellisle F, McDevitt R, Prentice AM. Meal frequency and energy balance. Br J Nutr. Apr;77 Suppl 1:S57-70, 1997.

Bingham 1987. Referred to in Manual of Dietetic Practice, 3rd edition, page 33, Briony Thomas, Blackwell publishing.

Bird SP, Tarpenning KM, Marino FE. Independent and combined effects of liquid carbohydrate/essential amino acid ingestion on hormonal and muscular adaptations following resistance training in untrained men. Eur J Appl Physiol. May;97(2):225-38, 2006.

Black AE, Prentice AM, Goldberg GR, Jebb SA, Bingham SA, Livingstone MB, Coward WA. Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake. J Am Diet Assoc. May;93(5):572-9, 1993.

Bujko J, Schreurs VV, Koopmanschap PE, Furstenberg E, Keller JS. Benefit of more but smaller meals at a fixed daily protein intake. Z Ernahrungswiss. 36(4):347-349, 1997.

Burke L. Nutrition for recovery after training and competition. Clinical sports nutrition, chapter 14, 3rd edition, Burke & Deakin, McGraw-Hill, 2006.

Børsheim E, Tipton KD, Wolf SE, Wolfe RR. Essential amino acids and muscle protein recovery from resistance exercise. Am J Physiol Endocrinol Metab. Oct;283(4):E648-57, 2002.

Børsheim E, Aarsland A, Wolfe RR. Effect of an amino acid, protein, and carbohydrate mixture on net muscle protein balance after resistance exercise. Int J Sport Nutr Exerc Metab. Jun;14(3):255-71, 2004.

Candow DG, Chilibeck PD. Effect of creatine supplementation during resistance training on muscle accretion in the elderly. J Nutr Health Aging. Mar-Apr;11(2):185-8, 2007.

Chromiak JA, Smedley B, Carpenter W, Brown R, Koh YS, Lamberth JG, Joe LA, Abadie BR, Altorfer G. Effect of a 10-week strength training program and recovery drink on body composition, muscular strength and endurance, and anaerobic power and capacity. Nutrition. May;20(5):420-7, 2004.

Cribb PJ, Hayes A. Effects of supplement timing and resistance exercise on skeletal muscle hypertrophy. Med Sci Sports Exerc. Nov;38(11):1918-25, 2006.

Cullinen K, Caldwell M. Weight training increases fat-free mass and strength in untrained young women. J Am Diet Assoc 98(4):414-8, 1998.

Cuthbertson D, Smith K, Babraj J, Leese G, Waddell T, Atherton P, Wackerhage H, Taylor PM, Rennie MJ. Anabolic signaling deficits underlie amino acid resistance of wasting, aging muscle. FASEB J. Mar;19(3):422-4, 2005.

Dangin M, Boirie Y, Guillet C, Beaufrère B. Influence of the protein digestion rate on protein turnover in young and elderly subjects. J Nutr. Oct;132(10):3228S-33S, 2002.

Daniels 1984, Krall & Dwyer 1987. Referred to in Clinical Sports Nutrition, 3rd edition, Burke & Deakin, McGraw-Hill, 2006.

Davies J, Parker DF, Rutherford OM, Jones DA. Changes in strength and cross sectional area of the elbow flexors as a result of isometric strength training. Eur J Appl Physiol Occup Physiol;57(6):667-70, 1988.

Demling RH, DeSanti L. Effect of a hypocaloric diet, increased protein intake and resistance training on lean mass gains and fat mass loss in overweight police officers. Ann Nutr Metab 44(1):21-9, 2000.

Esmarck B, Andersen JL, Olsen S, Richter EA, Mizuno M, Kjaer M. Timing of postexercise protein intake is important for muscle hypertrophy with resistance training in elderly humans. J Physiol. 2001 Aug 15;535(Pt 1):301-11, 2001.

FAO/WHO/UNU. Energy and protein requirements. 724. 1985. Geneva, WHO. World Health Organization: Technical report series.

Fostervold T. Effekt av måltidshyppighet på utvikling av muskelmasse og styrke. Masteroppgave i idrettsernæring, NIH, 2006.

Hartman JW, Tang JE, Wilkinson SB, Tarnopolsky MA, Lawrence RL, Fullerton AV, Phillips SM. Consumption of fat-free fluid milk after resistance exercise promotes greater lean mass accretion than does consumption of soy or carbohydrate in young, novice, male weightlifters. Am J Clin Nutr. Aug;86(2):373-81, 2007.

Hulmi JJ, Volek JS, Selänne H, Mero AA. Protein ingestion prior to strength exercise affects blood hormones and metabolism. Med Sci Sports Exerc. Nov;37(11):1990-7, 2005.

Ivy JL, Goforth HW Jr, Damon BM, McCauley TR, Parsons EC, Price TB. Early postexercise muscle glycogen recovery is enhanced with a carbohydrate-protein supplement. J Appl Physiol. Oct;93(4):1337-44, 2002.

Iwao S, Mori K, Sato Y. Effects of meal frequency on body composition during weight control in boxers. Scan J Med Sci Sports 6:265-272, 1996

Laskey MA. Dual-energy X-ray absorptiometry and body composition. Nutrition 1996; 12(1):45-51.

Lemon PW, Berardi JM, Noreen EE. The role of protein and amino acid supplements in the athlete's diet: does type or timing of ingestion matter? Curr Sports Med Rep. Aug;1(4):214-21, 2002.

Lenchik L, Kiebzak GM, Blunt BA; International Society for Clinical Densitometry Position Development Panel and Scientific Advisory Committee. What is the role of serial bone mineral density measurements in patient management? J Clin Densitom.;5 Suppl:S29-38, 2002.

Levenhagen DK, Gresham JD, Carlson MG, Maron DJ, Borel MJ, Flakoll PJ. Postexercise nutrient intake timing in humans is critical to recovery of leg glucose and protein homeostasis. Am J Physiol Endocrinol Metab. Jun;280(6):E982-93, 2001.

Loucks AB. Energy balance and body composition in sports and exercise. Journal of Sports Sciences 22, 1-14, 2004.

Louis-Sylvestre J, Lluch A, Neant F, Blundell JE. Highlighting the positive impact of increasing feeding frequency on metabolism and weight management. Forum Nutr;56:126-8, 2003.

Maughan RJ, Watson JS, Weir J. Strength and cross-sectional area of human skeletal muscle. J Physiol. May;338:37-49, 1983.

Mazzetti SA, Kraemer WJ, Volek JS, Duncan ND, Ratamess NA, Gomez AL, Newton RU, Hakkinen K, Fleck SJ. The influence of direct supervision of resistance training on strength performance. Med Sci Sports Exerc 32(6):1175-84, 2000.

Mosoni L, Mirand PP. Type and timing of protein feeding to optimize anabolism. Curr Opin Clin Nutr Metab Care. 2003 May;6(3):301-6, 2003.

Nindl BC, Harman EA, Marx JO, Gotshalk LA, Frykman PN, Lammi E, Palmer C, Kraemer WJ. Regional body composition changes in women after 6 months of periodized physical training. J Appl Physiol 88(6):2251-9, 2000.

Paddon-Jones D, Sheffield-Morre M, Aarsland A, Wolfe RR, Ferrando AA. Exogenous amino acids stimulate human muscle anabolism without interfering with the response to mixed meal ingestion. Am J Physiol Endocrinol Metab. 288, E761-E767, 2005.

Phillips SM, Tipton KD, Aarsland A, Wolf SE, Wolfe RR. Mixed muscle protein synthesis and breakdown after resistance exercise in humans. Am J Physiol. Jul;273(1 Pt 1):E99-107, 1997.

Phillips SM. Protein requirements and supplementation in strength sports. Nutrition 20(7-8):689-95, 2004.

Phillips, SM., Hartman, JW., Wilkinson, SB. Dietary protein to support anabolism with resistance exercise in young men. J Am Coll Nutr. 24(2):134S-139S, 2005.

Raastad T. Fysiologisk adaptasjon til styrketrening. Kompendium at NIH, 4th edition.

Raastad T, Karlsen S, Madsgaard S, Rønnestad BR, Kvamme N, Egeland W. Strength training and bone mineral density: The effects of exercise type, external load and training volumeon regional bone mineral content and density. Abstract ECSS, Jyväskylä, Finland, July 11-14th, 2007.

Racette SB. Creatine supplementation and athletic performance. J Orthop Sports Phys Ther. Oct;33(10):615-21, 2003.

Rankin JW, Goldman LP, Puglisi MJ, Nickols-Richardson SM, Earthman CP, Gwazdauskas FC. Effect of post-exercise supplement consumption on adaptations to resistance training. J Am Coll Nutr. 23(4):322-30, 2004.

Rasmussen BB, Tipton KD, Miller SL, Wolf SE, Wolfe RR. An oral essential amino acid-carbohydrate supplement enhances muscle protein anabolism after resistance exercise. J Appl Physiol. Feb;88(2):386-92, 2000.

Rennie MJ, Tipton KD. Protein and amino acid metabolism during and after exercise and the effects of nutrition. Annu Rev Nutr.;20:457-83, 2000.

Rennie MJ, Bohe J, Wolfe RR. Latency, duration and dose response relationships of amino acid effects on human muscle protein synthesis. J Nutr 132(10):3225S-7S, 2002.

Roy BD, Tarnopolsky MA. Influence of differing macronutrient intakes on muscle glycogen resynthesis after resistance exercise. J Appl Physiol. Mar;84(3):890-6, 1998.

Sinaki M. Exercise and osteoporosis. Arch Phys Med Rehabil. Mar;70(3):220-9, 1989.

Sinaki M, Khosla S, Limburg PJ, Rogers JW, Murtaugh PA. Muscle strength in osteoporotic versus normal women. Osteoporos Int. Jan;3(1):8-12, 1993.

Sosial- og helsedirektoratet. Mat og prestasjon, Kostholdsanbefalinger for idrettsutøvere, 2003.

Sosial- og helsedirektoratet. Norske næringsstoffanbefalinger, 2003.

Stote KS, Baer DJ, Spears K, Paul DR, Harris GK, Rumpler WV, Strycula P, Najjar SS, Ferrucci L, Ingram DK, Longo DL, Mattson MP. A controlled trial of reduced meal frequency without caloric restriction in healthy, normal-weight, middle-aged adults. Am J Clin Nutr. Apr;85(4):981-8, 2007.

Suominen H. Muscle training for bone strength. Aging Clin Exp Res. Apr;18(2):85-93, 2006.

Suzuki M. Glycemic carbohydrates consumed with amino acids or protein right after exercise enhance muscle formation. Nutr Rev. May;61(5 Pt 2):S88-94, 2003.

Tesch PA. Skeletal muscle adaptations consequent to long-term heavy resistance exercise. Med Sci Sports Exerc. Oct;20(5 Suppl):S132-4, 1988.

Thompson J, Manore MM. Predicted and measured resting metabolic rate of male and female endurance athletes. J Am Diet Assoc. Jan; 96(1):30-4. 1996.

Tipton KD, Ferrando AA, Phillips SM, Doyle D Jr, Wolfe RR. Postexercise net protein synthesis in human muscle from orally administered amino acids. Am J Physiol. Apr;276(4 Pt 1):E628-34, 1999a.

Tipton KD, Gurkin BE, Matin S, Wolfe RR. Nonessential amino acids are not necessary to stimulate net muscle protein synthesis in healthy volunteers. J Nutr Biochem. Feb;10(2):89-95, 1999b.

Tipton KD, Rasmussen BR, Miller SL, Wolf SE, Owens-Stovall SK, Petrini BE, Wolfe RR. Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. Am J Physiol Endocrinol Metab 281: E197-E206, 2001.

Tipton KD, Wolfe RR. Protein and amino acids for athletes. J Sports Sci. Jan;22(1):65-79, 2004.

Tipton KD, Elliott TA, Cree MG, Aarsland AA, Sanford AP, Wolfe RR. Stimulation of net muscle protein synthesis by whey protein ingestion before and after exercise. Am J Physiol Endocrinol Metab. 2007 Jan;292(1):E71-6, 2007.

Van Zant RS, Conway JM, Seale JL. A moderate carbohydrate and fat diet does not impair strength performance in moderately trained males. J Sports Med Phys Fitness. Mar;42(1):31-7, 2002.

Volek JS, Rawson ES. Scientific basis and practical aspects of creatine supplementation for athletes. Nutrition. Jul-Aug;20(7-8):609-14, 2004.

Volek JS, Forsythe CE, Kraemer WJ. Nutritional aspects of women strength athletes. Br J Sports Med. Sep;40(9):742-8, 2006.

Volpi E, Kobayashi H, Sheffield-Moore M, Mittendorfer B, Wolfe RR. Essential amino acids are primarily responsible for the amino acid stimulation of muscle protein anabolism in healthy elderly adults. Am J Clin Nutr. Aug;78(2):250-8, 2003.

Vågstrand K, Barkeling B, Forslund HB, Elfhag K, Linné Y, Rössner S, Lindroos AK. Eating habits in relation to body fatness and gender in adolescents--results from the 'SWEDES' study. Eur J Clin Nutr. Apr;61(4):517-25, 2007.

Westerterp-Plantenga MS, Kovacs EM, Melanson KJ. Habitual meal frequency and energy intake regulation in partially temporally isolated men. Int J Obes Relat Metab Disord. Jan;26(1):102-10, 2002.

Westerterp-Plantenga MS, Goris AH, Meijer EP, Westerterp KR. Habitual meal frequency in relation to resting and activity-induced energy expenditure in human subjects: the role of fat-free mass. Br J Nutr. 90(3):643-9, 2003.

Wilkinson JG, Liebmann M. Nutrition in exercise and sport (3rd edt) Boca Raton, FL; CRC, p.63-99, 1998.

Wilkinson SB, Tarnopolsky MA, Macdonald MJ, Macdonald JR, Armstrong D, Phillips SM. Consumption of fluid skim milk promotes greater muscle protein accretion after resistance exercise than does consumption of an isonitrogenous and isoenergetic soy-protein beverage. Am J Clin Nutr. Apr;85(4):1031-40, 2007.

Williams AG, van den Oord M, Sharma A, Jones DA. Is glucose/amino acid supplementation after exercise an aid to strength training? Br J Sports Med. Apr;35(2):109-13, 2001.

Willoughby DS, Stout JR, Wilborn CD. Effects of resistance training and protein plus amino acid supplementation on muscle anabolism, mass, and strength. Amino Acids.;32(4):467-77, 2007.

Young JC. Meal size and frequency: effect on potentiation of the thermal effect of food by prior exercise. Eur J Appl Physiol Occup Physiol. 70(5):437-41, 1995.

Yu CC, Sung RY, So RC, Lui KC, Lau W, Lam PK, Lau EM. Effects of strength training on body composition and bone mineral content in children who are obese. J Strength Cond Res 19(3):667-72, 2005.

Zernicke R, MacKay C, Lorincz C. Mechanisms of bone remodeling during weight-bearing exercise. Appl Physiol Nutr Metab. Dec;31(6):655-60, 2006.

List of appendices

Appendix 1. Information letter to participants

NORGES IDRETTSHØGSKOLE

BETYDNING AV MÅLTIDSFREKVENS FOR ØKNING I MUSKELMASSE OG STYRKE

VED STYRKETRENING

Dette er en forespørsel om du vil være forsøksperson i prosjektet **"Betydning av måltidsfrekvens for økning i muskelmasse og styrke ved styrketrening"**

HENSIKT

Kostholdets betydning for maksimal prestasjon og resultat i idrett har fått mer og mer oppmerksomhet de siste årene. I utholdenhetsidrett finnes det nå meget konkrete råd for hva slags karbohydrater man bør innta før og etter slik aktivitet, og videre hvilke mengder og ved hvilken hyppighet og "timing" inntaket bør skje i forhold til aktivitet. Lignende retningslinjer er foreløpig lite dokumnetert for optimal proteinsyntese etter styrketrening, en kunnskap som ville være av stor betydning for kraftidretter der maksimal styrke- og muskelmasse er sentralt.

Vi ønsker å gjennomføre et lengre treningsstudie, der vi vil prøve å få svar på hva slags måltidsmønster som gir best metabolsk miljø for muskelvekst og dertilhørende styrkeøkning. Denne typen kunnskap vil være av stor betydning for optimal resultatfremgang i styrke- og kraftidretter på samtlige ferdighetsnivåer.

GJENNOMFØRING AV PROSJEKTET

Vi ønsker å rekruttere 24 personer i alderen 20-35 år med minst 2 års erfaring med styrketrening. Du vil bli trukket inn i én av 2 grupper som skal trene etter samme treningsprogrammet i 12 uker. Dagskosten skal inntas med ulik måltidshyppighet i de to gruppene. Én gruppe (n=12) skal spise dagens mat fordelt på 6 mindre måltider, mens den andre gruppen (n=12) skal konsentrere matinntaket til 3 større måltider per dag. Du får spise mat som vanligvis inngår i kostholdet ditt, og du vil bli veiledet til å innta næringsstoffer og energi i henhold til generelle retningslinjer basert på matvarer i ditt opprinnelige kosthold.

Studieperioden på 14 uker innebærer 12 uker med ledsaget styrketrening. Treningen foregår 4 dager i uken med individuelt tilpasset belastning. Ingen annen regelmessig, intensiv trening kan forekomme i studieperioden.

Studieperioden innledes med styrketester (1RM[1] tester) for utvalgte muskelgrupper. Styrke testene gjentas i uke 4 og 8 av treningsperioden, og deretter etter treningsperioden (post-tester). Til sammen er det fire perioder med styrketester. I oppvarmingen før styrketestene vil du sykle på en ergometersykkel i 20 min på en belastning tilsvarende ca. 70% av ditt maksimale oksygenopptak. Du vil skifte mellom to ulike tråkkfrekvenser og vi måler hjertefrekvens, oksygenopptak, kraft i pedalene og opplevd grad av anstrengelse underveis. Du får også tilbud om å måling av maksimalt oksygenopptak på sykkel før og etter treningsperioden.

Før treningsperioden starter, gjennomføres en måling av kropps-sammensetning (DEXA; *dual energy x-ray absorption*) og av muskeltverrsnitt (MR; *magnetic resonance*). Dexa gjentas midt i treningsperioden, og begge til slutt etter treningsperioden. Det vil videre bli gjennomført en en veid kostregistrering og aktivitets-registrering i den innledende perioden.

Kostholdet vil kontrolleres og evnentuelt korrigeres gjennom treningsperioden med 4 stk 24-timers recall intervju.

TRENING

Treningsprogrammet vil være likt for begge gruppene, men du skal trene med individuelt tilpasset belastning. Treningsprogrammet vil bygges opp som et såkalt 2-splitt program, der kroppen deles inn i to hovedgrupper. Hver hovedgruppe trenes 2 ganger i løpet av uken (tilsammen 4 treningsdager), og har én tung treningsdag og én lett treningsdag. Den ene hovedgruppen består av følgende ben- og ryggøvelser; *knebøy, legextension, legcurl, tåhev, rygghev, sittende roing, romaskin,* samt *sit-ups* og *mageøvelse* i maskin. Den andre hovedgruppen består av følgende bryst-, arm- og skulderøvelser; *skulder sidehev, sittende nakkepress med hantler, fremoverlent sidehev, benkpress, incline brystpress, flyes, triceps nedpress, franskpress, biceps preachercurl, incline bicepscurl.* Treningen vil foregå på Norges Idrettshøgskole, og ved minst 2 økter/uke, optimalt ved samtlige 4 øktene, vil det være en instruktør til stede som kontakt og rettleder.

TESTER

Det blir tatt tverrsnittsbilder av låret (m.quadriceps femoris og hamstrings) og armen (m. biceps brachii og m. triceps brachii) ved hjelp av MR totalt 2 ganger i løpet av studieperioden. Dette for å måle eventuelle endringer i muskelstørrelse gjennom treningsperioden. Kroppssammensetningen vil også måles med DEXA før, midtveis i, og etter treningsperioden. Det gjøres 4 styrketester gjennom studieperioden; dette for å få mål på styrkeutviklingen, samt for å kunne justere treningsbelastningen i forhold til styrkeutviklingen.

En aktivitetsregistrering i forkant av treningsperioden legger grunnlaget for beregning av ditt daglige energibehov. Videre vil kostholdsregistrering i forkant av treningsperioden avklare om de enkelte trenger å endre noe på kosten for å møte studiets ønske for næringsstoffinntak. Fire 24-timers recall intervju midt i treningsperioden gjennomføres for å kontrollere kostholdet ditt gjennom treningsperioden.

[1] 1 repetisjon maksimum; den største motstanden du kan overvinne i en godkjent repetisjon.

FORDELER OG ULEMPER VED Å DELTA

Forsøket vil vare i tilsammen ca 14 uker. Det vil kreve mye av din oppmerksomhet, samt en del planlegging slik at trening og kostintervensjon passer inn i hverdagen din. Vi vil selvfølgelig gjøre vårt med å legge treningstidene til rette for deg, være til stede for å hjelpe deg under treningsøktene, samt å hjelpe deg med detaljert planlegging for det daglige kostholdet.

Du vil få mulighet til å gjennomgå en del tester som en vanligvis ikke får anledning til. De ulike testene vil vise deg hvordan din egen kropp reagerer og endrer seg i forhold til tilrettelagt styrketrening. Du vil få et profesjonelt treningsopplegg og nøye oppfølging under hele perioden. Du vil få økt kunnskap om kosthold og dets betydning for treningsresultater, og du vil dessuten selv være en viktig del i videreutviklingen av slik kunnskap.

Dersom det er noen spørsmål, ta kontakt med

Øyvind Hansen på tlf 97662800 (oyvind.hansen@studmed.uio.no)

eller Truls Raastad på tlf. 23 26 23 28 (truls.raastad@nih.no)

Hvis du etter å ha lest informasjonsskrivet ønsker å være med som forsøksperson eller er interessert i mer informasjon, ber vi deg kontakte oss innen 18.12.05 og du vil få nærmere beskjed om informasjonsmøte.

Det er frivillig å delta og du kan når som helst trekke deg fra prosjektet uten videre begrunnelse. Alle data vil bli anonymisert (kodet) før de blir lagt inn i en database.

Appendix 2. Presentation at information meeting with participants

NORGES IDRETTSHØGSKOLE

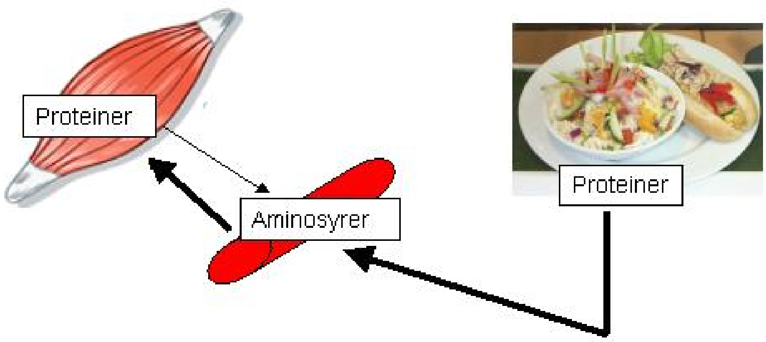
BETYDNING AV MÅLTIDSFREKVENS FOR ØKNING I MUSKELMASSE OG STYRKE VED STYRKETRENING

Therese Fostervold, Truls Raastad, NIH
Ina Garthe, Ernst Hansen, NIH
Øyvind Hansen, Det medisinske fakultet, avdeling for ernæringsvitenskap, UIO

NORGES IDRETTSHØGSKOLE

- Bakgrunn for å gjøre dette studiet;
  - For at en muskel skal stimuleres til å vokse, må den utfordres *over* sin eksisterende evne til kraftutvikling.
  - Byggestoffene i musklene er proteiner

Muskel ← **Protein** ← **Aminosyrer**



NORGES IDRETTSHØGSKOLE

- Sykkeltester i uke 2 og i uke 14:
  - Endring i muskelstyrke kan påvirke arbeidsøkonomi ved ulike tråkkfrekvenser
  - I oppvarming sykles det med 3 ulike frekvenser og HF og O_2-opptak måles
  - Du kan også få testet maksimalt O_2-opptak på sykkel før og etter styrketreningsperioden

NORGES IDRETTSHØGSKOLE

- Økning i styrke og muskelvolum=

  Trening + hvile + kosthold

- Treningsprogrammet;
  - 2-splitt; *ben/rygg/mage* og *skuldre/bryst/armer*
  - Periodiseringer; én tung og én lett økt pr program pr uke

    Uke 1-4: 8-12 repitisjoner
    Uke 5-8: 5-8 repitisjoner
    Uke 9-12: 2-5 repitisjoner
  - Ingen øvrig parallell trening (restitusjons dager!)
  - 1 uke innkjøring før studiet og testene starter
  - All trening skjer på Norges idrettshøgskole

NORGES IDRETTSHØGSKOLE

Ben/rygg/mage:

Knebøy*
Legextension
Sittende legcurl*
Tåhev
Rygghev
Liggende roing*
Sittende roing
Sit-ups
Magemaskin

Skulder/bryst/armer:

Stående hantel sidehev
Sittende skulderpress
Fremoverlent sidehev
Benkpress*
Incline brystpress
Liggende flyes
Triceps nedpress *
Franskpress
Preacher Curl*
Incline bicepscurl

**testøvelser i de seks 1RM styrketestene*

NORGES IDRETTSHØGSKOLE

- Hva slags effekt har måltidsrytmen på muskelstyrke og -hypertrofi stimuliet?

n = 12	n = 12
frokost	frokost
mellom	
lunsj	lunsj
middag	middag
mellom	
kvelds	

NORGES IDRETTSHØGSKOLE

n = 12		n = 12
Frokost	Individuelt energi inntak	**Frokost**
Mellom	>1,5 - 2 g proteiner/kg/dag	
Lunsj	< 30E% fett	**Lunsj**
Middag	~5-6g karbohydrat/kg/dag	**Middag**
Mellom		
Kvelds		

- Individuell aktivitetsregistrering i forkant av studiet
- 4 dagers veid kostregistrering i forkant av studiet

NORGES IDRETTSHØGSKOLE

- Prosjektet starter med en treningstilvennings uke i uke 1 (man 02.01)
- Trenings studiet går over 12 uker og starter i uke 2 (man 09.01) og varer fram til uke 13 (fre 31.03).
- Siste styrketester og kroppsmålinger skjer i uke 14 (man 03.04 – fre 07.04)

KOSTREGISTRERING **DAG 1**

FROKOST KL.....

Matvarer	gram
....	....
....	....
....	....
....	....

LUNSJ KL.....

Matvarer	gram
....	....
....	....
....	....
....	....

MIDDAG KL....

Matvarer	gram
....	....
....	....
....	....
....	....

NORGES IDRETTSHØGSKOLE

- Treningsskjema før studien starter;
  - Gir oss bakgrunns informasjons om deres treningserfaring
- Treningsdagbok gjennom studien;
  - 2 skjemaer;
    - Belastning brukt i styrketreningen
    - Øvrig fysisk aktivitet mm gjennom aktuell uke
  - Gir oss informasjon som er viktig i tolkningen av resultatene fra treningsperioden
  - Viktig å være ærlig!

NORGES IDRETTSHØGSKOLE

Januar

UKE	PLAN	MAN	TIRS	ONS	TORS	FRE	LØR	SØN
01	Kost reg Akt. Reg Tilvenning	2	3	4	5	6	7	8
02	DEXA, MR 1RM Treningsstart	9	10	11	12	13	14	15
03		16	17	18	19	20	21	22
04		23	24	25	26	27	28	29
05		30	31					

NORGES IDRETTSHØGSKOLE

Februar

UKE	PLAN	MAN	TIRS	ONS	TORS	FRE	LØR	SØN
05				1	2	3	4	5
06	1RM	6	7	8	9	10	11	12
07		13	14	15	16	17	18	19
08		20	21	22	23	24	25	26
09		27	28					

NORGES IDRETTSHØGSKOLE

Mars

UKE	PLAN	MAN	TIRS	ONS	TORS	FRE	LØR	SØN
09				1	2	3	4	5
10	1RM	6	7	8	9	10	11	12
11		13	14	15	16	17	18	19
12		20	21	22	23	24	25	26
13	Siste uke	27	28	29	30	31		

NORGES IDRETTSHØGSKOLE

April

UKE	PLAN	MAN	TIRS	ONS	TORS	FRE	LØR	SØN
13	**Siste uke**						1	2
14	DEXA, MR, 1RM	3	4	5	6	7	8	9
15	**Påske**	10	11	12	13	14	15	16
16	**Påske**	17	18	19	20	21	22	23
17		24	25	26	27	28	29	30

NORGES IDRETTSHØGSKOLE

- For å innkluderes i studiet, må du;
  - Være mellom 20 og 35 år
  - Ha trent styrketrening i minst 1 år
  - I de 10 forutgående ukene til studiet ikke ha brukt ergogene kosttilskudd*
  - Aldri ha brukt pro-hormoner eller anabole steroider
  - (Underveis i studiet ikke bruke kosttilskudd)
  - Underveis i studiet avstå fra å delta i annen organisert trening

** Produkter som påstås å øke prestasjonsevnen. Feks kreatin, koffein-tilskudd, karnitin og ginseng.*

Appendix 3. Training programme

PERIODE 1 Trenings uker 1-4

UKE: GRUPPE: NAVN:

DATO: TUNG ØKT: *BEN-RYGG-MAGE*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4	KG,SET 5
Knebøy maskin	X+12+10+[2*8]						
Legextension Sit. Legcurl	10 + 8 + 8 10 + 8 + 8						
Tåhev i benpress app.	12 + 10 + 8						
Rygghev	12 + 10 + 8						
Sittende roing Roing i maskin	10 + 8 + 8 10 + 8 + 8						
Sit up's benk 10°	12 +10+10						
Magemaskin	12 + 10 + 10						

Eventuelle kommentarer;

DATO: TUNG ØKT: *SKULDRE-BRYST-ARMER*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4	KG,SET 5
Stående hantel sidehev	12 + 10 + 8						
Sittende skulder press	10 + 8 + 8						
Framoverlent enarms sidehev	12 + 10 + 10						
Benkpress	X+10+8+[2*6]						
Incline brystpress 30 °	10 + 8 + 8						
Flyes 30°	12 + 10 + 8						
Triceps nedpress	10 + 8 + 8						
Franskpress	10 + 8 + 8						
Preacher Curl med kabel	10 + 8 + 8						
Sittende, incline bicepscurl	10 + 8 + 8						

Eventuelle kommentarer;

MÅLTIDSFREKVENS PROSJEKTET

2005-2006

PERIODE 1
Trenings uker 1-4

UKE:
GRUPPE:
NAVN:

DATO: LETT ØKT: *BEN-RYGG-MAGE*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG, SET 3	KG, SET 4
Knebøy maskin	X + [3*10]					
Legextension	12 + 10 + 10					
Sit. Legcurl	12 + 10 + 10					
Tåhev i benpress app.	[3*15]					
Rygghev	12 + 10 + 10					
Sittende roing	12 + 10 + 10					
Roing i maskin	12 + 10 + 10					
Sit up's benk 10 °	12 + 10 + 10					
Magemaskin	12+10+10					

Eventuelle kommentarer;

DATO: LETT ØKT: *SKULDRE-BRYST-ARMER*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG, SET 3	KG, SET 4
Stående hantel sidehev	12 + 10 + 10					
Sittende skulder press	12 + 10 + 10					
Framoverlent enarms sidehev	12 + 10 + 10					
Benkpress	X + [3*10]					
Incline brystpress 30 °	12 + 10 + 10					
Flyes 30 °	12 + 10 + 10					
Triceps nedpress	12 + 10 + 10					
Franskpress	12 + 10 + 10					
Preacher curl med kabel	12 + 10 + 10					
Sittende, incline bicepscurl	12 + 10 + 10					

Eventuelle kommentarer;

PERIODE 2
Trenings uker 5-8

UKE:
GRUPPE:
NAVN:

DATO: TUNG ØKT: *BEN-RYGG-MAGE*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4	KG,SET 5
Knebøy maskin	X+10+8+[2*5]						
Legextension	8 + 8 + 5						
Sit. Legcurl	8 + 8 + 5 + 5						
Tåhev i benpress app.	10 + 8 + 8						
Rygghev	10 + 8 + 8						
Sittende roing	X + 10 + 8 + 5						
Roirg i maskin	10 + 8 + 5 + 5						
Sit up's benk 10 °	10 + 8 + 5						
Magemaskin	10+8+8						

Eventuelle kommentarer;

DATO: TUNG ØKT: *SKULDRE-BRYST-ARMER*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4	KG,SET 5
Stående hantel sidehev	10 + 8 + 8						
Sittende skulder press	8 + 8 + 5						
Framoverlent enarms sidehev	10 + 8 + 8						
Benkpress	X+10+8+[3*5]						
Incline brystpress 30 °	8 + 8 + 5						
Flyes 30 °	10 + 8 + 8						
Triceps nedpress	10 + 8 + 5						
Franskpress	10 + 8 + 5						
Preacher Curl med kabel	8 + 8 + 5						
Sittende, incline bicepscurl	8 + 8 + 5						

Eventuelle kommentarer;

MÅLTIDSFREKVENS PROSJEKTET

2005-2006

PERIODE 2
Trenings uker 5-8

UKE:
GRUPPE:
NAVN:

DATO: LETT ØKT: *BEN-RYGG-MAGE*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4
Knebøy maskin	X + [3*10]					
Legextension	[3*10]					
Sit. Legcurl	[3*10]					
Tåhev i benpress app.	[3*10]					
Rygghev	[3*10]					
Sittende roing	[3*10]					
Roirg i maskin	[3*10]					
Sit up's benk 10 °	[3*10]					
Magemaskin	[3*10]					

Eventuelle kommentarer;

DATO: LETT ØKT: *SKULDRE-BRYST-ARMER*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG, SET 3	KG, SET 4
Stående hantel sidehev	[3*10]					
Sittende skulder press	[3*10]					
Framoverlent enarms sidehev	[3*10]					
Benkpress	X + [3*10]					
Incline brystpress 30 °	[3*10]					
Flyes 30 °	[3*10]					
Triceps nedpress	[3*10]					
Franskpress	[3*10]					
Preacher curl med kabel	[3*10]					
Sittende, incline bicepscurl	[3*10]					

Eventuelle kommentarer;

MÅLTIDSFREKVENS PROSJEKTET

2005-2006

PERIODE 3
Trenings uker 9-12

UKE:
GRUPPE:
NAVN:

DATO: TUNG ØKT: *BEN-RYGG-MAGE*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4	KG,SET 5
Knebøy maskin	X+10+8+[2*5]						
Legextension	8 + 8 + 5						
Sit. Legcurl	8 + 8 + 5 + 5						
Tåhev i benpress app.	10 + 8 + 8						
Rygghev	10 + 8 + 8						
Sittende roing	X + 10 + 8 + 5						
Roing i maskin	10 + 8 + 5 + 5						
Sit up's benk 10 °	10 + 8 + 5						
Magemaskin	10+8+8						

Eventuelle kommentarer;

DATO: TUNG ØKT: *SKULDRE-BRYST-ARMER*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4	KG,SET 5
Stående hantel sidehev	10 + 8 + 8						
Sittende skulder press	8 + 8 + 5						
Framoverlent enarms sidehev	10 + 8 + 8						
Benkpress	X+10+8+[3*5]						
Incline brystpress 30 °	8 + 8 + 5						
Flyes 30 °	10 + 8 + 8						
Triceps nedpress	10 + 8 + 5						
Franskpress	10 + 8 + 5						
Preacher Curl med kabel	8 + 8 + 5						
Sittende, incline bicepscurl	8 + 8 + 5						

Eventuelle kommentarer;

*Benkpress periodiseres videre; uke 9 og 10 som programmet viser. Uke 11 og 12: X + 8 + 5 + [3*3]

MÅLTIDSFREKVENS PROSJEKTET

2005-2006

PERIODE 3 **Trenings uker 9-12**

UKE: **GRUPPE:** **NAVN:**

DATO: LETT ØKT: *BEN-RYGG-MAGE*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG,SET 3	KG,SET 4
Kneboøy maskin	X + [3*10]					
Legextension	[3*10]					
Sit. Legcurl	[3*10]					
Tåhev i benpress app.	[3*10]					
Rygghev	[3*10]					
Sittende roing Roing i maskin	[3*10] [3*10]					
Sit up's benk 10 °	[3*10]					
Magemaskin	[3*10]					

Eventuelle kommentarer;

DATO: LETT ØKT: *SKULDRE-BRYST-ARMER*

ØVELSE	Repitisjoner	Innstilling	KG,SET 1	KG,SET 2	KG, SET 3	KG, SET 4
Stående hantel sidehev	[3*10]					
Sittende skulder press	[3*10]					
Framoverlent enarms sidehev	[3*10]					
Benkpress	X + [3*10]					
Incline brystpress 30 °	[3*10]					
Flyes 30 °	[3*10]					
Triceps nedpress	[3*10]					
Franskpress	[3*10]					
Preacher curl med kabel	[3*10]					
Sittende, incline bicepscurl	[3*10]					

Eventuelle kommentarer;

MÅLTIDSFREKVENS PROSJEKTET

2005-2006

Appendix 4. Weekly exercise diary

UKE:...... **ID.NR:**..........

TRENINGSDAGBOK

MANDAG dato:....................

Aktivitet Varighet Intensitet

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TIRSDAG dato:....................

Aktivitet Varighet Intensitet

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ONSDAG dato:....................

Aktivitet Varighet Intensitet

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TORSDAG dato:....................

Aktivitet Varighet Intensitet

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FREDAG dato:....................

Aktivitet Varighet Intensitet

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LØRDAG dato:....................

Aktivitet Varighet Intensitet

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....

SØNDAG dato:....................

Aktivitet Varighet Intensitet

....
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....

Appendix 5. 1RM test form

	1RM TEST-SKJEMA									Navn:..........	
PRE TEST											
			Rep antall →	12	10	7	3	1	1	1	1
			Belastning av r								
	ØVELSE	pparat innstillir	Forventet max	40 %	60 %	75 %	85 %	-5 %	max	5 %	5 %
	Knebøy			0	0	0	0	0	0	0	0
	Legcurl			0	0	0	0	0	0	0	0
	Liggende roing			0	0	0	0	0	0	0	0
	Benkpress			0	0	0	0	0	0	0	0
	Tricepsnedpress			0	0	0	0	0	0	0	0
	Preacher Curl			0	0	0	0	0	0	0	0
4 uker											
			Rep antall →	12	10	7	3	1	1	1	1
			Belastning av r	40 %	60 %	75 %	85 %	-5 %	max	5 %	5 %
	ØVELSE		Forventet max løft ↓								
	Knebøy			0	0	0	0	0	0	0	0
	Legcurl			0	0	0	0	0	0	0	0
	Liggende roing			0	0	0	0	0	0	0	0
	Benkpress			0	0	0	0	0	0	0	0
	Tricepsnedpress			0	0	0	0	0	0	0	0
	Preacher Curl			0	0	0	0	0	0	0	0
8 uker											
			Rep antall →	12	10	7	3	1	1	1	1
			Belastning av r	40 %	60 %	75 %	85 %	-5 %	max	5 %	5 %
	ØVELSE		Forventet max løft ↓								
	Knebøy			0	0	0	0	0	0	0	0
	Legcurl			0	0	0	0	0	0	0	0
	Roapparat			0	0	0	0	0	0	0	0
	Liggende roing			0	0	0	0	0	0	0	0
	Tricepsnedpress			0	0	0	0	0	0	0	0
	Preacher Curl			0	0	0	0	0	0	0	0
POST TEST											
			Rep antall →	12	10	7	3	1	1	1	1
			Belastning av r	40 %	60 %	75 %	85 %	-5 %	max	5 %	5 %
	ØVELSE		Forventet max løft ↓								
	Knebøy			0	0	0	0	0	0	0	0
	Legcurl			0	0	0	0	0	0	0	0
	Liggende roing			0	0	0	0	0	0	0	0
	Benkpress			0	0	0	0	0	0	0	0
	Tricepsnedpress			0	0	0	0	0	0	0	0
	Preacher Curl			0	0	0	0	0	0	0	0

Appendix 6. Activity registration

AKTIVITETSREGISTRERING

DAG 1;..onsdag..............................DATO;..... 04.jan **Navn;**

TID	AKTIVITET/GJØREMÅL	(intensitet)	*BMR-f*	
00.00-00.30				
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21.30-22.00				
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22.30-23.00				
23.00-23.30				
23.30-24.00				
			Total:	

DAG 2;....torsdag...........................DATO; ....05.jan **Navn;**

TID	**AKTIVITET/GJØREMÅL**	**(intensitet)**	***BMR-f***	
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21.30-22.00				
22.00-22.30				
22.30-23.00				
23.00-23.30				
23.30-24.00				
			Total:	

Appendix 7. Training history

TRENINGS HISTORIE

Id.nr:...........

TRENINGSALDER

1. Hvor mange år har du regelmessig trent minst 2g/uke (-eller mer) (gjelder all idrett)?

2. Hvor mange år har du regelmessig (>1g/uke) trent styrketrening (-med vekter!)?

TRENINGSMENGDE DET SISTE ÅRET

3. Hvor mange ganger i uken har du gjennomsnittlig trent det siste året (-gjelder all idrett!)?

4. Har du gjennom siste året regelmessig trent annen idrett; hvilken idrett er dette, og på hvilket nivå?
   Idrett;..
   Nivå; ;..

5. Hvor mange ganger i uken har du gjennomsnittlig trent styrketrening det siste året?

6. Bruker du personlig trener, instruktør, eller treningspartner i din styrketrening?

   a. Periodiserer du styrketreningen din?

   b. Har du benyttet deg av teknikker som "forced reps", "drop set", negative sett, pyramider mm?

Appendix 8. 4-days weighed registration

4-DAGERS KOSTREGISTRERING FOR IDRETTSUTØVERE

Navn: …………………………………………………………………..

Telefon: …………………………………………………………………..

E-mail: …………………………………………………………………..

Dato (fra-til): …………………………………………………………………..

Veiledning for kostregistreringen

- Du skal registrere kostholdet ditt i 4 dager (3 ukedager + 1 lørdag)
- Prøv å unngå at kostregistreringen forandrer matvanene dine - spis slik du vanligvis gjør!
- Skriv ned <u>alt</u> du spiser og drikker, også evt. kosttilskudd
- Skriv ned evt. væskeinntak og matinntak <u>under</u> trening også
- Start med det første måltidet den dagen registreringen begynner. Fyll inn de hoved- og mellommåltidene du spiser. For hvert måltid skal følgende skrives ned:

1) Klokkeslett

2) Navnet på matvaren eller retten → gi flest mulig opplysninger

   - Birkebeinerbrød, Norvegia ost F45, Nora jordbærsyltetøy, lett melk, 5 kr Freia melkesjokolade

   - oppskrift på hjemmelagete retter (skriv oppskriften bak på arket)

   - evt. hvordan retten er tilberedt (kokt, stekt)

3) Mengde av matvaren eller retten

   → oppgi mengde i gram hvis du har vekt

   → oppgi mengde i husholdningsmål hvis du ikke har vekt

   - antall, stykker, spiseskje, teskje, glass, kopp, dl

Ring hvis du har noen spørsmål; *# 97662800 eller oyvind.hansen@studmed.uio.no*

- Lever registreringen på Toppidrettsenteret i framlagt ringperm når du er ferdig
- Du vil bli kontaktet for time til kostveiledning når resultatene er klare

Lykke til!

Hilsen Øyvind Hansen

KOSTREGISTRERING DAG 1

FROKOST KL......................

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FROKOST KL.......................

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KOSTREGISTRERING DAG 3

FROKOST KL.....................

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KOSTREGISTRERING DAG 4

FROKOST KL......................

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Matvarer	Gram	*KODE*
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Matvarer	Gram	*KODE*
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Appendix 9. Dietary guidelines

Retningslinjer for kostplan til 3 vs 6 måltid studie

Inntak av energi og næringsstoffer

Energi
- Overskudd på 300 kcal daglig

Protein
- 1,4-1,8 gram/kg KV
- 15-20 E% (12-18 E%)

CHO
- 5-7 gram/kg KV
- 55-65 E% (50-65 E%)
- sukker < 10 E%

Fett
- 20-30 E% (mettet fett < 10 E%)

Kostfiber
- 30-35 gram daglig

Matvarevalg

Matvarevalg
- fortrinnsvis proteinkilder fra fisk/kylling, magre proteinkilder ved valg av kjøtt
- fiberrike karbohydratkilder med lavt-moderat sukkerinnhold
- fettkilder med umettet fett (fisk, fjærfe, rapsolje, olivenolje, nøtter)
- 750 gram frukt, bær, juice, grønnsaker
  - helst 2 porsjoner frukt og 3 porsjoner grønnsaker
  - helst 1 porsjon sitrusfrukt (vitamin C)

Hovedmåltidene
- kilde til karbohydrat: grovt brød, korn, pasta, ris, potet
- kilde til protein: melk/yoghurt, fiskepålegg, kjøttpålegg, egg, kjøtt/fisk/fjærfe
- kilde til antiox: juice, frukt, bær, grønnsaker

Middagsmåltid sammensetning
- 150 gram mager proteinkilde
- 150-200 gram pasta/ris/potet
- 200-300 gram grønnsaker/salat

Matvarevalg

Restitusjonsmåltid
- protein: 0,1 gram/kg KV
- karbohydrat: 1 gram/kg KV
- 2 dl drikkeyoghurt + 1 banan eller 1 stk Go'Morgen yoghurt fra TINE + mer karbohydrat

Appendix 10. 24-hours recall

DATO;............... DAG:........ ID NR:..............

24 timer recall intervju Nr.:..........

1. Når spiste du første gang i går? Klokken:.........................
   a. Hva spiste du, og hvor mye?
   b. Hva drakk du, og hvor mye?
   c. Noe mer????
2. Når spiste du neste gang? Klokken:.........................
   a. Hva spiste du, og hvor mye?
   b. Hva drakk du, og hvor mye?
   c. Noe mer????
   d. **EVNT:** Spiste du eller drakk du noe mellom disse måltidene?

3. Når spiste du neste gang? Klokken:.........................
    a. Hva spiste du, og hvor mye?
    b. Hva drakk du, og hvor mye?
    c. Noe mer????
    d. **EVNT:** Spiste du eller drakk du noe mellom disse måltidene?
4. Når spiste du neste gang? Klokken:.........................
    a. Hva spiste du, og hvor mye?
    b. Hva drakk du, og hvor mye?
    c. Noe mer????
    d. **EVNT:** Spiste du eller drakk du noe mellom disse måltidene?
5. Når spiste du neste gang? Klokken:.........................

a. Hva spiste du, og hvor mye?

b. Hva drakk du, og hvor mye?

c. Noe mer????

d. **EVNT:** Spiste du eller drakk du noe mellom disse måltidene?

6. Når spiste du neste gang? Klokken:.........................

   a. Hva spiste du, og hvor mye?

   b. Hva drakk du, og hvor mye?

   c. Noe mer????

   d. **EVNT:** Spiste du eller drakk du noe mellom disse måltidene?

Helt til slutt; *dra fram bilde-illustrering over matvarer som kan være glemt/oversett!*

Appendix 11. Weight registration form

VEIESKJEMA FOR MÅLTIDSFREKVENSPROSJEKTET

DELTAGER	20.sep	27.sep	04.okt	11.okt	18.okt	25.okt	01.nov	08.nov	15.nov	22.nov	29.nov	06.des	13.des

Deltagerne veies hver tirsdag før trening. Deltageren skal helst veies på samme tidspunkt hver tirsdag etter at de har vært på toalettet, og på samme vekt hver gang. Digital vekt lånes fra NIH (Truls) og tas med til treningsrom.