DIETARY HABITS OF COMPETITIVE CROSSFIT ATHLETES IN FINLAND

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CrossFit combines both intense, short period, and constantly varied exercises combining aspects of e.g. gymnastics, running, weightlifting, and rowing. Main performance qualities are measured by peak power and fatigue resistance. CrossFit community's official, yet anecdotal-evidence based dietary recommendations direct athletes to keep macronutrient intake as follows: 40 E% carbohydrate, 30 E% protein, and 30 E% fat. Conversely, according to research-based evidence higher carbohydrate intake levels at 50–70 E% are beneficial in high-intensity training.

Little is still known about the dietary habits of CrossFit athletes. The purpose of this study was to find out the dietary habits of competitive CrossFit athletes in Finland: potential associations with training volume and energy intake, as well as diet's energy intake and proportion of each macronutrient. The aim was also to assess whether the athletes' diets meet the various dietary recommendations: strength and power athlete, CrossFit, and Finnish dietary recommendations.

The data was collected between 29th June and 15th October 2017 from athletes (n=29, 17 males 28.9 ±5.4 years and 12 females 30.0 ±6.8 years) who had competed in the largest Finnish CrossFit competitions between 2015 and 2017 or had positioned themselves to top 100 athletes in Finland in the CrossFit world championship qualifications. The athletes filled three-day food and training diary, and a web-based questionnaire. Data was analysed with IBM SPSS Statistics 24 -software, and the food diaries were analysed utilising the Finnish food database Fineli.

The mean estimated energy balance for both genders was of -72 ±746 kcal. Mean estimated carbohydrate intake of 4.2 g/kg (41 E%) was below strength and power athlete and Finnish nutrition recommendations, but within CrossFit recommendations. Mean estimated protein intake of 2.5 g/kg (26 E%) met strength and power athlete and CrossFit recommendations. Mean estimated fat intake of 1.5 g/kg (34 E%) was within all dietary recommendations. Younger athletes were more likely to meet the carbohydrate intake recommendations for strength and power athletes (24.0 years vs. 30.2 years, p=0.006), Finnish recommendations for fat intake (28.1 years vs. 32.6 years, p=0.018) and CrossFit recommendations for total fat intake (28.2 years vs. 30.8 years, p=0.05).

CrossFit athletes' estimated intake on carbohydrate is inadequate in relation to strength and power athlete recommendations, but adequate in relation to CrossFit recommendations. Athletes should be aware that increase in training volume may result in decrease in energy balance (p=0.037) and in fat intake (p=0.007). Further research is warranted on potential performance effects of low intake of carbohydrates among CrossFit athletes.

ITÄ-SUOMEN YLIOPISTO, Terveystieteiden tiedekunta
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CrossFit on yhdistelmä intensiivisiä, lyhytkestoisia ja jatkuvasti vaihtelevia harjoituksia, jotka sisältävät muun muassa voimistelua, juoksua, painonnostoa ja soutua. Suorituskykyä mitataan huipputehon sekä väsymyksensietokyvyn kautta. CrossFit-yhteisön viralliset, kokemusperäiseen tietoon perustuvat ravitsemussuositukset ohjaavat urheilijoita pitämään makroravinteiden saannin seuraavanlaisena: 40 E% hiilihydraatteja, 30 E% proteiineja ja 30 E% rasvoja. Toisaalta, aikaisempien tutkimusten mukaan kovatehoisessa urheilussa hyödytään korkeahiilihydraattisesta ruokavaliosta (50–70 % energiansaannista).

CrossFit-urheilijoiden ravitsemuskäyttäytymisestä tiedetään vain vähän. Tämän tutkimuksen tarkoituksena oli selvittää CrossFit-kilpaurheilijoiden ravitsemuskäyttäytymistä Suomessa: mahdolliset yhteydet harjoitusmäärän ja energiansaannin kesken, energiansaanti, sekä eri makroravinteiden kokonaissaanti. Tavoitteena oli myös selvittää, noudattaako urheilijoiden ruokavalio voima- ja tehourheilijoiden, CrossFitin ja virallisten suomalaisten ravitsemussuosituksen linjauksia.

Aineistonkeruu tapahtui 29.6.-15.10.2017 urheilijoilta (n=29, 17 miestä 28,9 ±5.4 vuotta ja 12 naista 30,0 ±6.8 vuotta), jotka olivat kilpailleet suurimmissa suomalaisissa CrossFit-kisoissa vuosina 2015–2017 tai olivat sijoittuneet Suomessa 100 parhaan joukkoon CrossFitin maailmanmestaruuskisojen karsinnoissa. Urheilijat täyttivät ruoka- sekä harjoituspäiväkirjaa kolmen päivän ajan, sekä elektronisen kyselyn. Aineisto analysoitiin IBM SPSS 24:ssä, ja ruokapäiväkirjat analysoitiin käyttäen suomalaista elintarvikkeiden koostumustietopankki Fineliä.

Urheilijoiden arvioitu energiatasapaino oli -72 ±746 kcal. Keskimääräinen arvioitu hiilihydraattien saanti 4,2 g/kg (41 E%) alitti voima- ja tehourheilijoiden sekä suomalaiset ravitsemussuositukset, mutta saavutti CrossFit-suositukset. Arvioitu proteiinin saanti 2,5 g/kg (26 E%) saavutti voima- ja tehourheilijoiden sekä CrossFit-suositukset. Arvioitu rasvan saanti 1,5 g/kg (34 E%) saavutti kaikki ravitsemussuositukset. Nuoremmat urheilijat saavuttivat paremmin voima- ja tehourheilijoiden hiilihydraattien saantisuositukset (24.0-vuotiaat vs. 30.2-vuotiaat, p=0,006) sekä suomalaisten ravitsemussuositusten rasvansaannin (28,1-vuotiaat vs. 32,6-vuotiaat, p=0,018), ja myös CrossFit-suositusten rasvansaannin (28,2-vuotiaat vs. 30,8-vuotiaat, p=0,05).

CrossFit-urheilijoiden arvioitu hiilihydraattien saanti on riittämätöntä voima- ja tehourheilijoiden ravitsemussuosituksiin nähden, mutta riittävää CrossFit-suosituksiin nähden. Urheilijoiden tulee tiedostaa, että harjoitusmäärän lisääminen voi heikentää energiatasapainoa (p=0,037 sekä rasvansaantia (p=0,007). Lisätutkimuksia tarvitaan matalahiilihydraattisen ruokavalion mahdollisista vaikutuksista CrossFitin suorituskykyyn.

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ABBREVIATIONS

1RM	One-repetition maximum
24HR	24-hour dietary recall
ADP	Adenosine diphosphate
AEE	Activity energy expenditure
AMP	Adenosine monophosphate
AMRAP	As many rounds or repetitions as possible
ATP	Adenosine triphosphate
BCAA	Branched chain amino acid
BDNF	Brain-derived neurotrophic factor
BMI	Body mass index, kg/m^2
BV	Biological value
CFR	CrossFit dietary recommendations
CHO	Carbohydrate
CTL	Control group
E%	Share of total energy intake
EAA	Essential amino acid
FDR	Finnish dietary recommendations
FFA	Free fatty acid
FFM	Fat-free mass
FFQ	Food frequency questionnaire
g/kg	grams per kg^{-1} body weight
HIIT	High-intensity interval training
HR_{max}	Maximum heart rate
MET	Metabolic equivalent
NO	Potassium nitrate oxide
PDCAAS	Protein-digestibility corrected amino acid score
pO_2	Partial pressure of oxygen in the capillary blood
RMR	Resting metabolic rate
SD	Standard deviation
SPR	Strength and power athlete dietary recommendations
SUP	Supplement group
TDEE	Total daily energy expenditure
TEF	Thermic food effect
THL	Finnish National Institute for Wealth and Welfare, Terveyden ja hyvinvoinnin laitos
VO_2	Submaximal exercise oxygen uptake
VO_{2max}	Maximal exercise oxygen uptake
WHO	World Health Organisation
WOD	Workout of the day
Yrs	Years

1 INTRODUCTION

CrossFit was founded in the 1990s by Greg Glassman, who as a gymnast wanted to achieve superior physical performance compared to bodyweight-trained gymnasts. In 1995 Glassman founded a gym to Santa Cruz California, which quickly expanded to a large CrossFit community. CrossFit Inc. was founded in 2000 and nowadays the company owns and operates CrossFit worldwide as a sport and as a trademark. (Farrar 2012)

CrossFit is a fitness regimen designed to advance overall health and fitness (CrossFit.com 2017a). It is a combination of intense, short period and diverse exercises combining gymnastics, Olympic lifts, anaerobic training and cardiorespiratory activities at high power (Bellar et al. 2015). CrossFit's goal is to create the so-called "Fittest men and women on Earth" where optimised physical fitness is defined as top-level features in endurance, strength, mobility, power, speed, coordination, agility, balance and accuracy (Glassman 2002).

CrossFit training is mainly based on metabolic conditioning (metcon) and it can improve aerobic capacity, cardiovascular fitness as well as body composition within three-month training program (Murawska-Cialowicz et al. 2015). CrossFit program relies highly on actual data on performance as every workout has strict rules and standards, scores and records are counted on every WOD (workout of the day), and whiteboards are used to mark scores. Philosophy behind CrossFit is to prepare everyone for the unknown and unknowable. (CrossFit.com 2017a)

The number of CrossFit affiliate boxes i.e. gyms is globally over 13,000 in 120 countries, and the number of people training the sports is around 4 million worldwide (Wang 2016; CrossFit.com 2017a). In Finland, there are around 70 CrossFit boxes (Appendix 1) (CrossFit.com 2017c). CrossFit Inc. collects yearly licencing fees from its affiliates who have the right to use CrossFit name and logo in their business (CrossFit.com 2017b).

As CrossFit is a relatively young sport, research conducted on nutrition and CrossFit is limited to-date. Previous research on CrossFit and nutrition has focused mainly on nutritional supplements (Outlaw et al. 2014; Escobar et al 2016; Kramer et al. 2016; Rountree et al. 2017), and research has also been conducted to study the physiology (Babiash et al. 2013; Bellar et al. 2015; Murawska-Cialowicz et al. 2015; Nieuwoudt et al. 2017), effects of training on immune responses (Tibana et al. 2016), athlete epidemiological profile (Sprey at al. 2016), performance (Butcher et al. 2015), injury rates (Meyer et al. 2017; Moran et. al 2017), and safety for military fitness training (Poston et al. 2016).

Previous studies generally agree that high-carbohydrate intake and improved performance correlate with each other, whereas among CrossFit community, low-carbohydrate intake has gained popularity. The American College of Sports Medicine (ACSM*)* (2016) concluded that high-carbohydrate intake affects the ability to maintain exercise performance in prolonged and intermitted or sustained high-intensity exercise. McArdle et al. (2010) also emphasised that nutrition in high-intensity sports should be compiled from 50–70 E% of carbohydrates, 20–30 E% of proteins and 30–45 E% of fats. For the optimum health, performance and results in training, nutrition plays an important role (Aerenhouts et al. 2010).

On the other hand, CrossFit's official dietary recommendations suggest that the intake should be divided to 40 E% of carbohydrates, 30 E% of proteins and 30 E% of fats, which is believed to represent healthy and macronutrient-balanced nutrition. CrossFit's founder Glassman (2002) stated that diet consisting of 70 E% of carbohydrates, 20 E% of proteins and 10 E% of fats leads to elevated risk of cancer, diabetes, and heart disease or results in weak physical performance. Still, dietary recommendations used within the CrossFit community are mainly based on anecdotal rather than on research-based evidence (Escobar et al. 2016).

The aim of this research was to assess the dietary habits of competitive CrossFit athletes in Finland. More specifically, does the energy intake correlate with training volume, what is the proportion between various macronutrients, and are there potential factors common to many of the athletes? Goal is also to gain insight on whether the athletes' diets follow the official dietary recommendations of CrossFit or other dietary recommendations.

2 LITERATURE REVIEW

2.1 CrossFit

CrossFit can be classified as high-intensity interval training (HIIT) as it constitutes of various functional movements, combinations of exercises and repetitions within a limited time frame or with a limited number of repetitions (Kramer et al. 2016). The exercises are usually performed quickly, repetitively and with limited or without recovery time between the sets, and the workouts are often "scored" based e.g. on the time required to complete the workout or the amount of repetitions completed (Poston et al. 2016; Sprey et al. 2016). Therefore, there is a great deal of variation based on each WOD. Each workout can be scaled based on individual's current fitness level, which makes the training program efficient (Meyer et al. 2017).

CrossFit exercise routines are varied, as three-day training period is followed by one rest day, which is again followed by three-day training period. Periodisation aims to maximise exercise endurance and intensity. (Glassman 2002) The training protocol includes endurance, strength, speed, power, and coordination, and CrossFit training utilises the whole kinematic chain of the body (Murawska-Cialowicz et al. 2015). WODs are constantly varied by length (between 2 to 60 minutes), loads, and repetitions (Glassman 2002). One of the most well-known benchmark WODs are presented in Appendix 2.

CrossFit's philosophy is based on a hierarchy where optimal nutrition creates the base for development in metabolic fitness (Figure 1). According to Glassman (2002), nutrition creates the foundations for example in developing one's strength qualities i.e. weightlifting and throwing (Figure 1, step 4). Going through systematically the hierarchy upwards is beneficial especially in the case of deficiencies or difficulties in athlete's performance. (Glassman 2002)

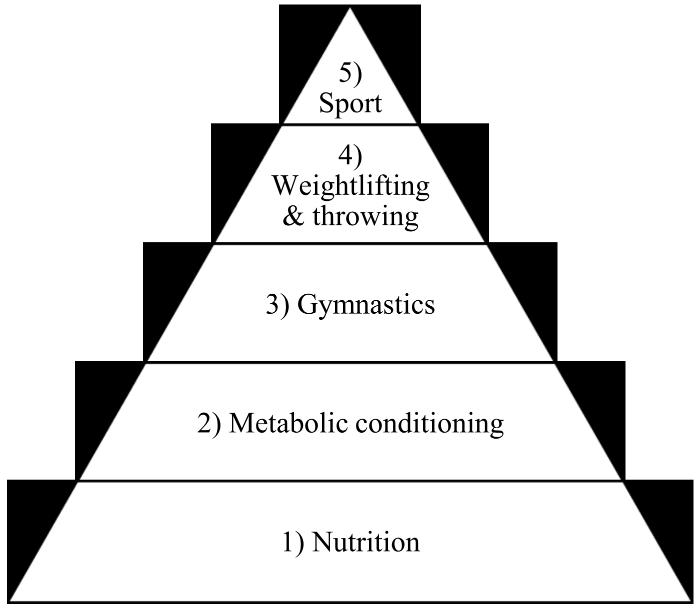

Figure 1. A theoretical hierarchy of development in CrossFit (modified according to Glassman 2002).

2.1.1 CrossFit physiology

Performance in CrossFit is affected especially by the peak power and the ability to resist fatigue, as the workouts are characterised by short-duration and high-intensity (Kramer et al. 2016). One competition event may include e.g. running up to 800 meters combined with weightlifting movements. Thus, both aerobic and anaerobic capabilities are needed within the training method. (Bellar et al. 2015)

Like other high-intensity training programs, also CrossFit improves VO_{2max}, musculature, and endurance, and decreases lean body mass (Murawska-Cialowicz et al. 2015; Meyer et al. 2017). Murawska-Cialowicz et al. (2015) stated that the resting levels of brain-derived neurotrophic factor (BDNF) increased during 3-month CrossFit training program for fit and healthy males and females without prior experience in CrossFit. BDNF is a protein stimulating neuron production within the body, and exercise enhances the release of BDNF during exercise. Therefore, CrossFit may improve the connections between muscular and nervous systems and improve the physiological adaptation of exercise. (Murawska-Cialowicz et al. 2015)

Due to CrossFit, changes in acid-base balance potentially indicates post-exercise increase of partial pressure of oxygen in the capillary blood (pO_2). Blood's oxygen capacity and the body's capability to perform long-term exercises improved due to increased number of capillaries and increased blood saturation at rest and post-exercise. In the study, pulmonary ventilation increased by 9 % after 3-month training program. (Murawska-Cialowicz et al. 2015)

A study conducted by Babiash et al. (2013) concluded that CrossFit improves the aerobic capacity likely more efficiently compared to traditional aerobic training performed below the anaerobic threshold. In the study 16 healthy moderate to very fit individuals with no prior experience in CrossFit were tested for energy expenditure and relative exercise intensity. The participants performed two WODs: The first named Donkey Kong included three rounds of burpees, kettlebell swings and box jumps with repetition scheme on the first round being 21, second round 15 repetitions, and third round 9 repetitions. The second WOD Fran included thrusters and pull-ups with same repetition scheme as the first WOD. The average energy expenditure was 21 kcal/min for males and 12 kcal/min for females. Heart rate elevated up to 90 % of maximum heart rate (HR_{max}) for the whole duration of both WODs, and mean VO_{2max} met 80 % indicating exercise above the anaerobic threshold. Blood lactate was 15.9 mmol/L for males and 12.4 mmol/L for females on average. (Babiash et al. 2013)

In Nieuwoudt et al.'s study (2017) CrossFit was used as an intervention training protocol for sedentary (<1 hour of exercise/week) type 2 diabetes patients (n=12, aged 54 ±2 years, fasting glucose 166 ±16 mg/dl). The participants had no previous history of CrossFit training, and they were assigned for supervised training for three times a week for six weeks. Participants' actual abdominal body fat (p=0.005) and mean total body fat percentage (p=0.003) were decreased significantly, whereas no changes in lean body mass were observed (p=0.94). Hence, CrossFit training is an effective method for β-cell function improvements for patients with type 2 diabetes. (Nieuwoudt et al. 2017)

2.1.2 CrossFit competitions

CrossFit is based on the philosophy of being sport that creates the fittest men and women in the world, and CrossFit has its own world championship competitions, the CrossFit Games. Once a year through qualification competitions Open and Regionals, 40 male and 40 female athletes compete against each other at the CrossFit Games. Qualifications to the CrossFit Games begin from the Open in Spring, which last for five weeks with one workout announced each week. Anyone can join to the Open, perform the workouts, and submit their scores to the CrossFit website. After the Open, top athletes from 17 regions worldwide are qualified to participate in the Regionals that last for three days in May–June. Based on the scores in the Regionals, top athletes qualify for the CrossFit Games held in Autumn at USA. (CrossFit Inc. 2017)

Besides the CrossFit Games, many local CrossFit affiliates organise their own CrossFit competitions that resemble national championships. In Finland, currently the largest and most important national competitions are Karjalan Kovin organised by CrossFit Lappeenranta in Imatra, Unbroken organised by CrossFit 8000 in Espoo, and Winter War organised by Reebok CrossFit 33100 in Tampere. All the competitions include a qualification phase, where athletes perform one or more qualification workouts couple of weeks or months before the main event. The best-performed male and female athletes from the qualifications are granted a permission to compete in the main competition.

Karjalan Kovin has 55 male and 55 female competitors in the general series, 10 competitors in the 40+ age group and 5 competitors in the 50+ age group (Karjalan Kovin 2015). Winter War and Unbroken have 32 male and 32 female competitors, and Unbroken has also a team series (Unbroken 2018; Winter War 2018).

2.2 Energy intake and energy availability

Nutrition is extremely important factor for success of competitive power and strength athletes (Slater and Phillips 2011). Athletes with result-oriented mindset need to focus on content, timing, and amount of food. Besides to training, high quality nutrition is essential for athletes' performance and recovery. (Ilander 2014a) ACSM (2016) state that energy intake and energy expenditure of the exercise (energy availability) create the most important basis for successful sports nutrition and health maintenance design. Also, the nutritional timing and support throughout the day and keeping the sport's requirements in mind are important factors when designing nutrition. (ACSM 2016)

2.2.1 Sources of energy

Macronutrients carbohydrates, proteins, and fats are the sources of energy. In addition, alcohol can also be classified as an energy source. Energy from macronutrient oxidation is transformed into adenosine triphosphate (ATP), which functions as an energy source for all the cell's processes requiring energy. In muscles, ATP provides energy for every form of biologic work. Further, ATP is transformed into adenosine diphosphate (ADP) and adenosine monophosphate (AMP) in the process of macronutrient oxidation. (McArdle et al. 2010)

In the body ATP is stored in a format of triglycerides and glycogen. Glycogen storages in cells are limited and resynthetisation is essential following the rate of ATP use. Phosphocreatine serves also as an immediate energy source and as an energy reservoir, and it is stored in muscles and nerve tissue for rapidly to be transformed into energy in anaerobic conditions, especially at the beginning of exercise. Phosphocreatine storages in muscles are also limited. (McArdle et al. 2010) Food consumed is therefore a direct link to energy intake and to the body's ability to perform in every-day life.

2.2.2 Energy production during exercise

ACSM's (2016) recommendations emphasise that proper nutrition form the basis in athlete's diet as it guarantees optimal functions for body, assists in shaping the body composition and specifies the macronutrient and micronutrient capacity of the body. According to McArdle et al. (2010), mixture of sources for energy expenditure in exercise depends on the intensity and duration of effort as well as on the fitness and nutritional status of the athlete. As a reference point, McArdle et al. (2010) and Ilander (2014c) stated that as the intensity of the training increases, so does the use of carbohydrates for energy (Figure 2). As seen here, carbohydrates are in an important role in the CrossFit fuel mixture, as the VO_2 may reach up to 80 % of VO_{2max} within a workout (Babiash et al. 2013).

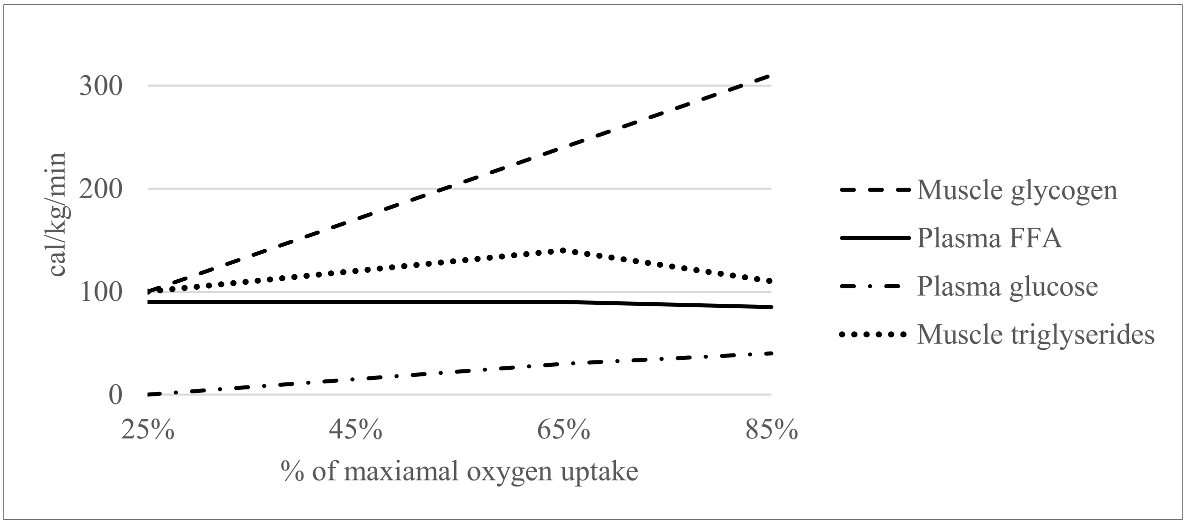

Figure 2. Caloric contribution of muscle glycogen and triglyceride storage, and plasma free fatty acids (FFA) and glucose in relation to exercise intensity (modified according to Ilander 2014c).

Fogelholm (2009) pointed out that intensity of training effects on the energy sources (Figure 3). Carbohydrates are an essential factor in energy production on all intensity levels, as the proportion varies approximately between 45 % and 95 %, whereas the proportion of proteins and fats may in some situations be close to zero. (Fogelholm 2009)

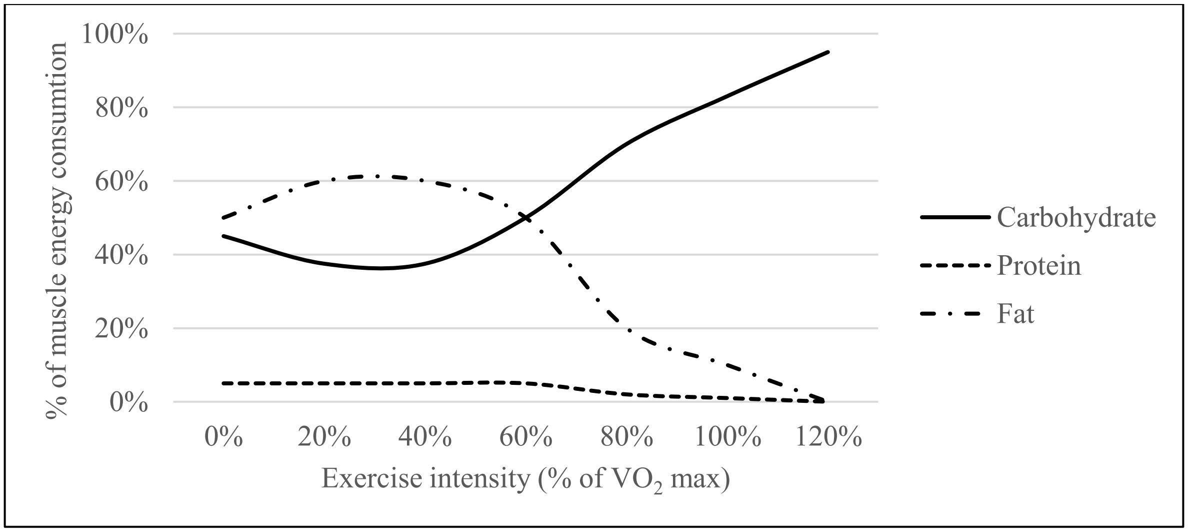

Figure 3. Carbohydrate, protein and fat proportion of energy expenditure in muscles on different intensities. Intensity of 100 % refers to anaerobic energy production (modified according to Fogelholm 2009).

As weightlifting performances are typically short duration and anaerobic by nature, the energy production mostly takes place in glycogenolysis and glycolysis in muscles. Type IIb muscle fibres are primarily used in weightlifting, and therefore carbohydrates are the main energy source. (Mutanen and Voutilainen 2016) Escobar et al. (2016) also stressed the importance of glycogenolysis as an energy production mechanism in CrossFit. Glycogenolytic energy production is high and continuous in CrossFit, as it demands the ability to maintain maximal power and to be exposed to high-intensity cardiorespiratory activities. Therefore, too low intake of carbohydrates may result in reduced performance. (Escobar et al. 2016)

2.2.3 Energy intake

Nutrition has three important roles in strength-power sports, as it acts 1) as a fuel for the body in the strength-training, 2) as a recovery substance from the training, and 3) as a promoter for the adaptations of the training, e.g. skeletal muscle hypertrophy. Relatively high rate of energy intake because of phosphagen energy system and glycolysis, contribution subject to relative power output, as well as level of blood flow in the muscles and work-to-rest ratio are factors required in resistance training. Interestingly, metabolic fatigue in the beginning of the workout may be a result of low levels of storage in phosphagen energy system and mild acidosis. The later the fatigue occurs, the more potential factors causing it are acidosis and decreased energy production from glycogenolysis. (Slater and Phillips 2011)

The energy intake for athletes should be over 30 kcal/lean body mass but levels in practice are usually between 28–32 kcal/lean body mass (Ilander 2014a). Endurance training requires more energy compared to resistance training due to higher intensity and longer duration of the exercises. Usually resistance training athletes are not in a risk for a negative energy balance compared to endurance training athletes, as endurance training may attenuate appetite (exercise induced anorexia). (Deighton et al 2013; Ilander 2014a)

2.2.4 Energy availability

Energy availability stands for equation "*energy intake – energy expenditure caused by exercise = energy availability kcal / kg (fat-free mass) / day"* (Ilander 2014a). Energy expenditure is therefore a result of energy expended for the body's metabolic work (Loucks et al. 2011). Energy availability is in key role for athlete efficiently to train, recover and develop performance, and therefore energy availability must be on right level for the athlete to improve performance (Table 1).

To estimate energy availability, information about the mean daily energy intake and mean daily energy expenditure is needed. Energy intake can be measured by using food diaries and energy expenditure with heart rate monitors. Fat-free mass can be measured with simple bioimpedance sensors. (Ilander 2014a)

TABLE 1. Levels for energy availability and effects for athletes (modified according to Ilander 2014a).

Energy availability (kcal/kg fat-free mass)	Effect for athletes
>45	High energy availability: Optimal performance, recovery, muscle mass and strength development. Body mass may increase[a].
40-45	Moderate energy availability: Adequate training response, performance development and health. No changes in body mass.
30-40	Low energy availability: Slow decrease in body mass. If made reasonable, no impairments in health, body composition and performance.
<30	Very low energy availability: Not recommended. Impairs training response and muscle mass, and increases the risk for injury, hormonal imbalance, osteopenia, and disease. No changes or slow decrease in body mass after rapid decrease in the beginning due to adaptations in thermogenesis.

[a]High energy availability may not cause increase in fat mass as thermogenesis increases the overlapping energy supplies.

Inadequate energy intake weakens the recovery process from training, as glycogen stores do not refuel to the optimum level (Burke et al. 2011). Reasons for inadequate energy availability for athletes are varied: obsessive eating disorder associated with clinical mental illnesses, intentions to rationally improve performance by reducing fat-mass and/or body size with mismanaged ways e.g. weight-loss, fasting, laxatives, and vomiting. Inadequate energy intake may also result from excessive training volume unintentionally. (Loucks et al. 2011)

2.2.5 Methods to assess energy intake and energy expenditure

Dietary habits and actual energy and food intakes can be assessed by collecting food diaries, performing a food frequency questionnaire, and interviewing the participants with 24-hour dietary recall. All methods have their strengths and limitations especially related to their accuracy, cost-efficiency, and time required to collect the data. (Shim et al. 2014)

2.2.5.1 Food frequency questionnaire and 24-hour dietary recall

Food frequency questionnaire (FFQ) handles dietary habits for a relatively long period, such as previous six months, and the questionnaire includes close-ended questions. FFQ has low accuracy as it relies on the participant's memory, although it is relatively simple, and cost- and time-efficient. (Shim et al. 2014)

24-hour dietary recall (24HR) also relies on the participant's memory, as it assesses the food consumed within the last 24 hours. Respondent burden is relatively small, as literacy is left for the interviewer. The method requires a trained interviewer, and therefore collecting data with 24HR is time-consuming and expensive to perform. In addition, to guarantee accuracy, multiple days are required to count the average intakes. On the other hand, data collection methods can be combined by merging 24HR, food diary, and checklist for usually consumed foods. (Shim et al. 2014)

2.2.5.2 Food diary

Collecting data using food diaries is common for assessing the actual dietary habits for short period of time. Food diaries focus on reporting the actual food and drink consumption over specific days, and the food records rely fully on participant's literacy. Consumed amounts of foods are usually estimated by the participant, and the quantification is based on common household measures such as grams and table spoons. (Fuller et al. 2016) Detailed information about food consumption allows to make thorough analyses about the participant's nutritional status. Participants must be responsive and willing to cooperate, and therefore research focused on children and elderly mainly utilises 24-hour dietary recalls instead of food diaries as a data collection method. (Lahti-Koski and Rautavirta 2012)

As each individual consumes various amounts between various days (intra-individual variability) and individuals consume various amounts compared to other participants (inter-individual variability), considerations must be made on the length of the reporting period. Three-day food diaries are widely used when assessing average food consumption of specific population group. Also, if the sample population reaches 50 participants, one-day food diaries are adequate. (Lahti-Koski and Rautavirta 2012)

Three-day estimated food diary is usually a better approach instead of a seven-day weighed food record, as the burden for participants becomes greater as the reporting period extends (Fuller et al. 2016). Also, when measuring food consumptions, individual diet seasonality between days and seasons, individual amounts consumed on specific portions, database information about the foodstuffs, and methods used to measure food consumption have to be considered (Männistö 2012).

Food diary data may include errors and biases, errors being characterised as random and common to all individual in the specific population, whereas biases affect the results due to variability in food consumption e.g. methods used to collect the data and the level of the country where the population lives in. Bias may be caused by variations in energy intake between seasons, weekdays and weekends and in case of underreporting. (Rossato and Fuchs 2014) Underreporting is very common when collecting data via self-reported food diaries. Underreporting may occur in several cases, e.g. when the respondent burden is too excessive, participants do not eat as they would normally do, participants choose not to eat too complicated foods as those take more time to record, snacks and alcohol are not consumed as would be the case on a normal day, or specific foodstuffs are simply not recorded to the diary. This whitewash may occur also in other food measurement methods, not purely on food diaries. (Lahti-Koski and Rautavirta 2012)

Underreporting has been investigated to be between 18 to 54 % within the non-bodybuilding population (MacDiarmid and Blundell 1998). Interestingly, according to Klingberg et al. (2008), overreporting was more common within 18 to 20-year-old males compared to underreporting, where total 10 % of participants were overreporters. ACSM (2016) pointed out that explaining the documentation purposes and protocol for the participants, the possibility for inaccuracy of self-reported food records may be reduced.

2.2.5.3 Assessing energy expenditure

Physical activity logs are widely used for clinical research purposes as they are low in costs, non-invasive, and easy to administrate. Respondents usually log their physical activity over a certain period of time, e.g. over seven days. Activity energy expenditure is then calculated using the energy equivalents for each activity. (Lam and Ravussin 2016)

As this research focused on measuring the correlation between energy intake and energy expenditure, it is important to understand factors affecting these variables. The total daily energy expenditure (TDEE) includes three aspects (Figure 4): resting metabolic rate (RMR), thermic effect of food (TEF) and activity energy expenditure (AEE). TEF can also be called as diet-induced thermogenesis. (Lam and Ravussin 2016) Energy balance exists when energy intake is equivalent to TDEE (ACSM 2016).

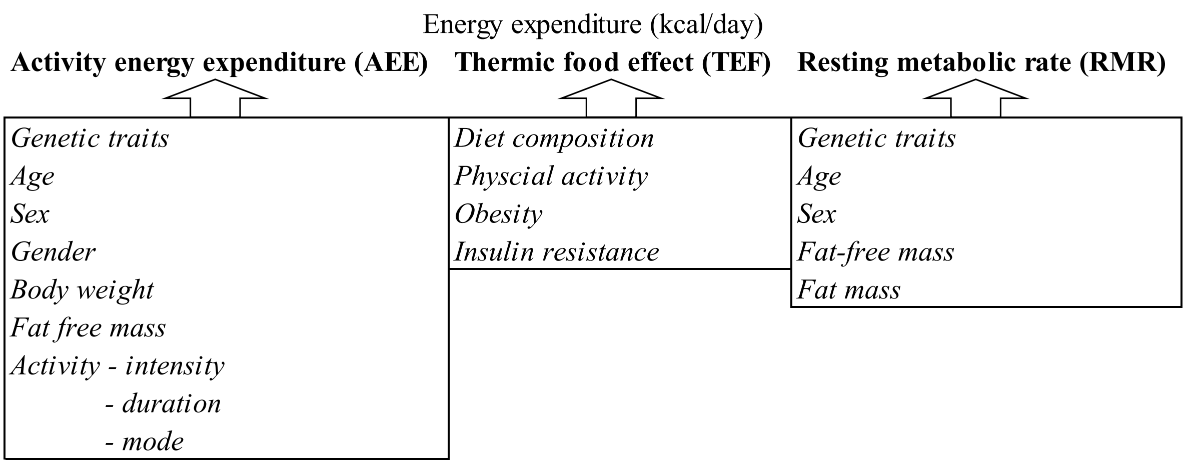

Figure 4. Total daily energy expenditure (TDEE) components. (modified according to Hills et al. 2014; Lam and Ravussin 2016).

For sedentary individuals, the RMR results for 70 % of TDEE, and for athletes RMR may result to 38–47 % of TDEE (ACSM 2016; Lam and Ravussin 2016). Fat-free mass (FFM) is the main factor affecting total RMR as it results approximately to 70 % of RMR. The rest 30 % of RMR consists of factors behind gender, age, and familial traits. The maintenance of core body temperature at +37 °C results to two-thirds of RMR. (Lam and Ravussin 2016)

Carlsohn et al. (2011) pointed out that athletes usually have different RMR compared to the general population due to larger total body mass and FFM. As FFM affects the athlete RMR significantly, for athletes the share of RMR of TDEE may differ compared to nonathletes. It is common that RMR is underestimated especially for heavyweight male endurance athletes whereas for females the predictions are usually accurate. In conclusion, equations used to calculate RMR for athletes with high FFM may make significant underestimations, approximately 150–200 kcal/day. (Carlsohn et al. 2011)

TDEE's main determinant is energy cost of physical activity as it may even result to 50 % of TDEE for individuals that are highly active. For more sedentary individuals the proportion is assumed to be 15 % of total TDEE. TEF is affected by energy used for food consumption (digesting, absorbing, assimilating and storing the nutrients). (Lam and Ravussin 2016)

Nevertheless, energy intake and energy expenditure usually create balance between each other, and weight changes and performance levels are good indicators for this (Ilander 2014a). Estimated TDEE is calculated with the following equation:

TDEE (kcal/24h) = Physical Activity Level (PAL) x RMR

Calculations for RMR can be done using different equations. Mifflin-St. Jeor can be used for obese and normal weight individuals, whereas Owen has been useful for young and slim females (Ilander 2014a). World Health Organisation's (WHO) (2001) framework for calculating the RMR was used in this research (Table 2).

- *Mifflin-St. Jeor*
  - *RMR for females = 9,56 x weight (kg) x 1,85 x height (cm) – 4,68 x age + 655,1*
  - *RMR for males = 13,75 x weight (kg) x 5 x height (cm) – 6,76 x age – 66,47*
- *Owen*
  - *RMR for females = 7,18 x weight (kg) + 795*
  - *RMR for males = 10,2 x weight (kg) + 879*

TABLE 2. WHO basal metabolic rate equation (World Health Organisation 2001).

Gender and age (yrs)	Equation
Males	
0–3	(60.9 * weight) – 54 kcal
3–10	(22.7 * weight) + 495
10–18	(17.5 * weight) + 651
18–30	(15.3 * weight) + 679
30–60	(11.6 * weight) + 879
>60	(13.5 * weight) + 487
Females	
0–3	(61.0 * weight) – 51 kcal
3–10	(22.5 * weight) + 499
10–18	(12.2 * weight) + 746
18–30	(14.7 * weight) + 496
30–60	(8.7 * weight) + 829
>60	(10.5 * weight) + 596

2.3 Dietary recommendations for strength and power athletes

ACSM (2016) states that optimal daily protein intake should be between 1.2–2.0 g/kg, carbohydrate intake between 3–12 g/kg depending on the intensity of the exercise, and fat intake between 20 E% and 35 E% of total energy intake. (Table 3)

TABLE 3. Recommendations for carbohydrate intake by athletes (modified according to ACSM 2016 and Burke et al. 2011).

Intensity	Type of exercise	Carbohydrate intake (g/kg)
Light	Low intensity / skill-based	3–5
Moderate	Moderate, e.g. 1 hour per day	5–7
High	Endurance program, e.g. 1–3 hours per day moderate to high-intensity exercise	6–10
Very high	Extreme commitment, e.g. >4–5 hour per day moderate to high-intensity	8–12

As CrossFit can be classified as high-intensity exercise program, the daily carbohydrate intake is suggested to be kept between 6–10 g/kg. Although fat provides energy for aerobic conditions and the magnitude of ATP production is larger compared to carbohydrate, carbohydrate offers superior yield in relation faster energy production and in anaerobic conditions. (ACSM 2016)

When considering the emphasis between various macronutrients (carbohydrates, proteins and fats), according to Ilander (2014b) it can be done based on the following Table 4. Food group that gained the most hits (marked with *) should be emphasised the most in the athlete's nutrition. (Ilander 2014b)

TABLE 4. Macronutrients to be emphasised in sports (modified according to Ilander 2014b).

	Vegetables and fruits	**Carbohydrates**	**Proteins**	**Fats**
Type of sport	***Skill**	***Endurance/ power**	***Strength**	***Endurance**
Need for energy	Small	***Large**	Small and/or energy intake limited	***Large**
Energy intake			Small and/or energy intake limited	Limited and/or menstrual periods are irregular Carbohydrate intake limited
Goal(s)	Improve weight control Reduce fat mass and maintain muscle mass Maintain and promote health and reduce strains	***Increase muscle mass**	***Increase muscle mass** Reduce fat mass and maintain muscle mass ***Improve strength** Improve weight control	Maintain and promote health and reduce strains
Amount of training		***High**		***High**
Length of training sessions		Long		
Season	Rehabilitation from injury or illness	Off-season	Rehabilitation from injury or illness	Off-season
Other		***Lots of high-intensity training and want to improve quality of training**		
Total score	**1**	**5**	**3**	**3**

n.a. = not applicable

As seen in the Table 4, CrossFit nutrition should focus mainly on carbohydrates, and after that on proteins and fats equally – total score for carbohydrates is 5, for proteins and fats 3, and for the group "vegetables and fruits" 1. According to these conclusions, CrossFit's official dietary recommendations (Glassman 2002; Escobar 2016) are in line with Table 4.

2.3.1 Carbohydrates

Carbohydrates constitute of monosaccharides, disaccharides, oligosaccharides, and fibres and they are used for energy production, sparing proteins from catabolism, functioning as metabolic primer for fat catabolism, and providing energy for the central nervous system. Carbohydrates are mainly stored in muscles as glycogen, and the nutrients are used for energy during anaerobic exercise as well as during longer-duration endurance exercises. Muscle glycogen stores provide fuel for anaerobic energy production for 30 to 120 seconds, whereas within aerobic energy production the storages last for 45 to 120 minutes. The amount of muscle glycogen in the body for person weighing 70 kilograms is approximately 325 grams, which equals to 1,365 kcal. Glycogen stores in liver equal to 100 grams and 420 kcal, and blood glucose to 15 grams and 56 kcal. (McArdle et al. 2010)

According to Krings et al. (2016), ingesting 15 grams of carbohydrate during resistance training improves ($p<0.05$) performance in relation to repetition volume. Low-carbohydrate diet is considered to impair exercise capacity and the ability to sustain high-intensity aerobic exercise due to depleted muscle and liver glycogen. On the other hand, excess amounts of carbohydrate are stored as fat in the body. (McArdle et al. 2010) CrossFit training's metabolic profile is glycogenolytically-demanding, and therefore diet including moderately-low levels of carbohydrates may not provide tools for improving performance. Demand on high and continuous glycogenolytic energy production is due to sport-specific high cardiorespiratory activities which increase the need for glycogen utilisation and availability. (Escobar et al. 2016)

The body's carbohydrate storages are limited which allows the acute manipulation of the reserves. By increasing or decreasing the daily carbohydrate intake from food or performing a single strenuous exercise, the carbohydrate storage levels may be changed one way or another, although the capacity of carbohydrate storages is fixed. (McArdle et al. 2010)

Skeletal muscle glycogen stores may decline by 33 % (±7 %) following a single 45-minute resistance exercise session with repetition scheme of 10 reps for three sets (Koopman et al. 2006). Hence, athletes whose training focuses on strength and power are highly recommended to maintain moderate- or high-levels of carbohydrates in their diets (4–10 g/kg) (Escobar et al. 2016). Ilander (2014c) recommended keeping the daily carbohydrate intake between 5–10 g/kg in strength and power sports, where the weekly amount of training is between 10 and 20 hours. Physical exercise and low-carbohydrate diet increase protein catabolism, and therefore it is important for athletes to keep body's glycogen stores at optimal level to prevent loss of muscle mass (McArdle et al. 2010).

When viewing the energy expenditure during resistance training, it is concluded that one session can shrink glycogen storages by 24–40 %. The decrease in volume is dependent on the intensity, length, and total completed work in the exercise. Therefore, the carbohydrate intake is recommended to be kept between 4 and 7 $g \cdot kg^{-1}$ body mass. (Slater and Phillips 2011) McArdle et al. (2010) recommended carbohydrate intake to be kept at 60 E% at minimum for physically active people, and at 70 E% when training is done in high-intensity. These amounts equal to 6–10 g/kg, and the nutrient sources should be unrefined and fibre-rich fruits, vegetables and grains. (McArdle et al. 2010)

According to Burke et al. (2011), restoring the liver and muscle glycogen storages after each training event is essential for recovery. Carbohydrate intake recommendations should be based on body mass and exercise load, not on percentage on the total daily energy intake. (Burke et al. 2011) Taken this into account, the official CrossFit recommendations for carbohydrate intake (40 E%) are not adequate.

Escobar et al. (2016) found out that carbohydrate-rich diet (6–8 g/kg) (CHO group) did not create significant difference in repetitions completed in 12-minute CrossFit workout (AMRAP: 12 box jumps, 6 thrusters and 6 bar-facing burpees) compared to control group which kept carbohydrate intake below 6 g/kg. The duration of this randomised trial was nine days and included a total of 18 participants, 9 in each of the groups. The CHO group increased the carbohydrate intake from days 6 to 8 whereas the control group kept intake consistent.

Escobar et al. (2016) suggested that diets such as Zone and Paleo with carbohydrate intake of 40 E% of daily energy intake may be adequate for short periods of time but probably not over extended periods of training e.g. weeks and months. This conclusion is due the fact that there were no differences in exercise performance despite the difference in CHO intake between the two groups. (Escobar et al. 2016)

2.3.2 Proteins

Proteins constitute from amino acids of which eight are essential for adults and to be consumed from food, and nine are non-essential amino acids. Proteins function as contributors to tissue structure or constitutors of metabolic, transport and hormonal systems. Stores of protein do not exist in the body as the major sources are blood plasma, visceral tissue, and muscles. Amino acids are the most important factors for tissue synthesis. (McArdle et al. 2010)

Recommended daily protein intake is 1.2–1.8 g/kg and therefore exaggeration is not necessary even in case of high-intensity training. This is because excessive dietary protein may cause damaging side effects especially related to liver and kidneys. Overconsumed protein is catabolised for energy or is stored as component for other molecules such as fat. (McArdle et al. 2010) ACSM's (2016) recommendations set basis for daily protein intake (1.2–2.0 g/kg), and it must be equally divided throughout the day. Protein intake exceeding 2.0 g/kg may be useful in case of reduced energy intake and short periods of intensified training. (ACSM 2016) In this case protein intake equals to 20–30 E% of total daily energy intake.

According to Slater and Phillips (2011), protein intake should be between 1.6–1.7 $g \cdot kg^{-1}$ body mass for strength-training athletes. It is assumed, that intense resistance training phase lowers the need for dietary protein as it improves the retention of net protein and decreases the protein turnover (Slater and Phillips 2011). Overall, to provide optimal protein synthesis and to avoid amino acid oxidation, energy intake especially from carbohydrates should match energy expenditure (ACSM 2016). Protein helps to restore the muscle glycogen stores when carbohydrate intake does not meet the requirements for refuelling. Nine studies viewed the glycogen storages after 2 to 6 hours of exercise with different rates of carbohydrate ingestion and with or without protein co-ingestion. They all concluded that glycogen synthesis can be improved with the addition of protein when the carbohydrate intake is under the requirements for glycogen restorage (<1.2 g/kg). (Burke et al. 2011)

Protein from dairy products such as whey protein has the optimum protein quality, as it provides ultimate stimulation for muscle protein synthesis compared to e.g. soy protein. This is likely due to better contents of essential amino acids (EAAs) and branched chain amino acids (BCAAs). (Rindom et al. 2016) In addition, whole milk and lean meat as whole food protein sources provide increase in muscle protein synthesis (ACSM 2016). Protein types are usually ranked by its biological values (BV) and protein-digestibility corrected amino acid score (PDCAAS). BV with the highest value of 100 refers to how efficiently the exogenous protein type results to protein synthesis after absorption. Bovine milk with 80 % casein and 20 % of whey has BV of 91, casein has BV of 77, whey 104, and soy 74. PDCAAS ranks protein types based on the contents of essential amino acids with maximum value of 1.00. Bovine milk, casein, whey, and soy protein have all PDCAAS value of 1.00. (Stark et al. 2012)

Stark et al.'s (2012) review conducted on protein timing and type stated that timing the protein ingestion pre- and/or post-workout increases physical performance, recovery, lean body mass, strength, and muscle hypertrophy. The type and amount of protein ingested affect the specific gains and consuming 3–4 grams of leucine on each meal results in maximal protein synthesis. Leucine requires simultaneous ingestion of insulin in the shape of e.g. maltodextrin or glucose to enable optimum post-workout protein synthesis. On the other hand, consumption of dextrose together with protein is found to evoke protein synthesis prior resistance training. (Stark et al. 2012) To augment the optimum muscle protein synthesis, protein intake of 0.25–0.3 g/kg or 15–25 grams should be scheduled immediately after exercise, around 0 to 2 hours. Dietary protein intake exceeding 40 grams has not proven to enhance the muscle protein synthesis (ACSM 2016).

2.3.3 Fats

Lipids aka fats constitute the body's largest store for potential energy, and they are also used for transporting the water-soluble vitamins A, D, E, and K, protecting organs and insulating from the cold. The energy for low- to moderate-intensity exercise is provided mostly for 50 to 70 % by fatty acids, and for prolonged exercises the body's own fat stores become essential providing up to 80 % of energy. (McArdle et al. 2010)

ACSM (2016) recommended keeping fat intake between 20 and 35 E% of total energy intake. McArdle et al. (2010) also stated that intake should be kept at 30–45 E% at maximum, and 70 % of the total fat intake should be unsaturated. Fat intake is profitable to be kept between 20 and 30 E% as low-fat diet diminishes the normal increase in plasma testosterone followed by resistance training, which again leads to impaired performance, poorer training response, and tissue synthesis (McArdle et al. 2010). Dietary fat intake below 20 E% may also lead to reduced intake of various nutrients including fat-soluble vitamins and essential fatty acids (ACSM 2016). For supplying energy to maintain body weight and muscle mass, the body requires an increase in carbohydrate and protein intake during resistance training, which again is made more difficult during low-fat diet. On the other hand, fat ensures adequate energy intake (McArdle et al. 2010).

Increasing the fat intake above 30 E% at the expense of carbohydrates, performance is not improved (McArdle et al. 2010). In case fat intake is below 20 E% of total energy intake, the supply of fat-soluble vitamins and essential fatty acids (e.g. n-3) may be decreased. Therefore, reductions in fat intake should be done with careful consideration and in case of pre-event diet or carbohydrate-loading due to gastrointestinal comfort or preferred macronutrients. (ACSM 2016)

2.3.4 Fluid

The body loses water daily through respiration, indigestion, kidneys, and sweating, and excess heat from muscle work is dissipated through sweating, which results to water loss.

Air temperature and other environmental factors also affect the body temperature. Muscle contractions during physical exercise create metabolic heat, which may lead to decrease in plasma and blood volume (hypovolemia), which again may cause cardiovascular strain, altered metabolic function, increased utilisation of glycogen, and rise in body temperature. Combined with dehydration, the events may cause breakneck heat illness, heat stroke. Therefore, athletes must avoid dehydration. (ACSM 2016)

Sweat contains water and significant amounts of sodium, and lesser amounts of calcium, magnesium, and potassium. These electrolytes are in great importance of maintaining body's homeostasis and optimal body function, as well as wellbeing and performance. Therefore, athletes are encouraged to execute accurate fluid management at pre-, during and post-exercise phases. Dehydration >2 % of body weight within hot air temperature affects the performance in aerobic exercises and the cognitive function. On the other hand, high-intensity and anaerobic performance skills usually decrease with dehydration of 3–5 % of body weight within cool air temperature. In case the dehydration reaches 6–10 % of body weight, the exercise tolerance, cardiac output, production of sweat, as well as blood flow in muscles and skin are impaired. (ACSM 2016)

Fluids should be consumed 5–10 ml/kg of body weight 2 to 4 hours before exercise. As the amount of sweat varies based on the exercise intensity, heat acclimatisation, altitude, duration, and athlete's level of fitness, athletes should consume 0.4–0.8 litres per hour during exercise to avoid dehydration. Excess drinking of fluids may result in hyponatremia aka water intoxication, where blood sodium levels exceed 135 mmol/L in case the loss of sodium is not replaced consuming sodium-rich fluids. Due to smaller body size and lower rates of sweat, females are usually in greater risk of hyponatremia. (ACSM 2016)

Post-exercise fluid strategies include moderate levels of water and sodium. The recommended intake is 125 % to 150 % of the fluid deficit, e.g. 1.25–1.5. L of fluid against every lost 1 kg of body weight during exercise. Excessive levels of diuretics such as alcohol and caffeine (>180 mg) should be avoided at the post-exercise phase. (ACSM 2016)

2.3.5 Dietary supplements

Supplement-use is relatively common among strength and resistance training, and the most commonly used supplements are various vitamins, protein powders, amino acid supplements, caffeine, and creatine monohydrate. (Slater and Phillips 2011)

2.3.5.1 Carbohydrate and protein supplements

Pre- and post-workout protein-carbohydrate supplements improved performance in CrossFit athletes in Outlaw et al.'s (2014) open-label randomised study. Participants (n=29, 13 males and 16 females) had been training CrossFit for at least the previous six months for three times a week. The six-week long study protocol included performance testing for supplement group (SUP) and for control group (CTL) in two WODs in addition to tests for body composition, VO_2max, and Wingate peak and mean power. WOD1 consisted of 500-meter row, 40 wall balls, 30 push-ups and 20 box jumps for time, whereas WOD2 was to complete the following in 15 minutes: 800-meter row in addition to AMRAP of 5 burpees, 10 kettlebell swings and 15 air squats. (Outlaw et al. 2014)

The pre-workout supplement was taken 30 minutes before testing, and it included 19 g of pomegranate extract, tart cherry, and green and black tea. Post-workout supplement had 20/40 grams (females/men) of protein and 40/80 grams of carbohydrate. The benchmark WODs and testing were performed at baseline and after six weeks. CTL consumed only water before and after the workouts. The mean improvement for SUP in WOD1 was -38.79 seconds (CTL -8.62 seconds) and in WOD2 +16.79 reps (CTL +6.31 reps), and hence the improvements were potentially meaningful. (Outlaw et al. 2014)

Urbina et al. (2013) conducted a six-week open-label randomised study on pre- and post-workout supplement's effect on CrossFit performance and body composition. The athletes (n=24, 11 males and 13 females) had been training CrossFit for at least six months. Study design was closely similar to Outlaw et al. (2014) research: 19 g pre-workout drink had pomegranate fruit, beet root and tart cherry extract, and green and black tea, and it was consumed by SUP 30 minutes before the workouts. Post-workout drink had 40/80 grams of protein (females/men) and 80/160 grams of carbohydrate. CTL did not consume anything one hour before and after the workouts. (Urbina et al. 2013)

Participants performed WOD1 (500-meter row, 40 wall balls, 30 push-ups, 20 box jumps, and 10 thrusters for time) as well as WOD2 (800-meter run followed with 15 minutes AMRAP: 5 burpees, 10 kettlebell swings, and 15 air squats) at baseline and after six weeks. Other performance factors besides result in WOD1 (p=0.05) did not improve significantly. WOD1 performance improved for SUP -58.33 ±52.31 secs (10.43 %) whereas CTL improved only by -3.66 ±14.38 secs (0.73 %). Urbina et al. (2013) concluded that pre- and post-workout supplement use has beneficial effects on CrossFit-specific performance. (Urbina et al. 2013)

On the other hand, Rountree et al. (2017) found out that carbohydrate ingestion during CrossFit exercise did not improve athlete performance in a randomised controlled trial. Eight study participants (22 ±1.8 years, height 177 ±7 cm and body mass 81.3 ±7.2 kg) took part in four trials with at least seven days in between. Third and fourth trial utilised double-blinded, randomised crossover design, with carbohydrate (6 % sucrose/dextrose solution) or placebo beverage during the exercises. On the first trial participants could choose a beverage they preferred, and on the second trial they were supplied only with CHO beverage. The exercise conducted on each of the trials was WOD Fight Gone Bad that included five rounds of maximal repetitions of wall balls, box jump, sumo deadlift high pull, push press, and rowing followed by one minute of rest. (Rountree et al. 2017) Kulik et al.'s (2008) randomised double-blinded study (n=8 males) also concluded that carbohydrate supplementation during high-intensity resistance training did not improve performance when testing five repetition squats to exhaustion (85 % of 1RM).

Given these beforementioned and contradictory results, there is still a limited amount of nutritional intervention research within CrossFit specific performance. This was acknowledged also by Rountree et al. (2017).

2.3.5.2 Nitric oxide

Nitric oxide as a chronic dietary supplement improved peak power performance for male CrossFit athletes. Kramer et al.'s (2016) 40 days long double-blinded, randomised and cross-over design studied the effects of 8 mmol·d−1 potassium nitrate (NO) to performance in peak power (30 second Wingate test with cycle ergometer), strength, endurance, CrossFit WOD Grace (for time: 30 clean and jerks), and in 2 km rowing time trial. The supplement was consumed 24 hours prior the performance tests. NO significantly ($p=0.01$) increased peak power, but no other statistically significant improvements were noted in other performance areas. The supplement caused gastrointestinal discomfort for five participants in the NO group and interestingly also for three people in the placebo group. (Kramer et al. 2016)

Nitric oxide has also been found to reduce the metabolic cost of exercise. Wylie et al. (2016) found out reductions in submaximal exercise oxygen uptake (VO_2) within their randomised four-week trial. Participants (n=34) were grouped either to receive 3 mmol of NO, 6 mmol NO or placebo, and the effect of supplements were tested by two moderate-intensity step exercise tests. The reduction in submaximal exercise VO_2 was significant in the 6 mmol NO group two hours after ($p=0.06$) and 7 days as well as 4 weeks after chronic supplementation ($p<0.05$). (Wylie et al. 2016)

Muscle speed and power was also increased by acute NO intake in Coggan et al.'s (2015) randomised, double-blind, placebo-controlled crossover study (n=12). The participants performed a knee extensor test after consuming 11.2 mmol of NO or placebo. The peak knee extensor power increased for the SUP group to 7.90 ±0.59 from baseline 7.44 ±0.53 W/kg ($p<0.05$). (Coggan et al. 2015)

2.4 CrossFit dietary recommendations

Currently as the studies done particularly in CrossFit athletes are lacking, no scientific consensus about the ideal diet for CrossFit athletes exists. This is probably the main reason why trend diets such as Zone and Paleo have gained such a great popularity among CrossFit athletes. Escobar et al. (2016) were however criticising these moderately-low level carbohydrate diets, as by using these, athletes may not be able to reach the optimal performance levels required in CrossFit. For short periods of training such as three days, diet including moderate levels of carbohydrates may be an adequate solution for performance demands. However, over an extended period of training such as weeks and months, insufficiency in carbohydrate intake unavoidably depletes glycogen stores and impairs performance. (Escobar et al. 2016)

Zone and Paleo diet guidelines on macronutrient intakes are mainly based on E% of daily energy intake rather than on g/kg as only Zone diet has recommended g/kg values for protein intake (Stulnig 2015). Research conducted on Paleo diet have based macronutrient intakes on E% of daily energy intake (Frassetto et al. 2009; Manheimer et al. 2015) and on total daily amount in grams (Mashrani et al. 2015; Otten et al. 2017).

2.4.1 Zone diet

Within the CrossFit community, athletes are encouraged to follow either Paleo or Zone diet (Escobar et al. 2016). Zone aims to keep macronutrient proportion as follows: 40 E% carbohydrates, 30 E% proteins and 30 E% fats, and it is determined mainly based on protein intake which should be kept between 1.8 and 2.2. g/kg (FFM) (Cheuvront 1999; Stulnig 2015). More precisely, the Zone diet aims to keep the energy intake as low as possible without feeling the hunger. Proteins are supposed to maintain positive nitrogen balance in the body, and low-glycaemic carbohydrates on the other hand ensure insulin-glucagon balance. According to Sears and Bell (2004), sources of fat should be mainly polyunsaturated, and saturated fat and omega-6 fatty acids should be avoided. (Sears and Bell 2004)

Zone diet is described as an anti-inflammatory diet, as the goal is to choose nutrients that do not promote chronic inflammation in the body. The main goal for Zone diet is to keep the key hormone levels on a therapeutic zone, as dietary macronutrients effect directly insulin/glucagon and eicosanoid levels. (Sears and Bell 2004) Stulnig (2015) stated that Zone diet has been successful in reducing the low-grade inflammation on specific variables such as C-reactive protein, tumour necrosis factor-α and interleukin-6 compared to diet which consisted of 55 E% carbohydrates, 15 E% protein and 30 E% fat. Zone diet also seemed to beneficially change the insulin demands for patients with type 2 diabetes. (Stulnig 2015)

For weight loss, Zone diet and other low-carbohydrate diets resulted in greater results compared to e.g. low-fat diets. Statistically significant differences between different diets existed but were nonetheless small. Johnston et al. (2014) concluded in their meta-analysis that for weight loss all low-carbohydrate and low-fat diets are suitable compared to non-existing dietary intervention. (Johnston et al. 2014)

One of the Zone diet's marketing clauses is that it changes the body's hormonal milieu which leads to increased level of vasoactive eicosanoid production, resulting in improved delivery of oxygen to the exercising muscle (Cheuvront 1999). Jarvis et al. (2002) conducted a 7-day research on Zone diet's effects on athletic performance for endurance athlete males (n=8). The diet resulted in significant reductions ($p<0.05$) in time to exhaustion trial (pre-test 37.68 ±8.6 minutes to after diet 34.11 ±7.01 minutes). Body mass and caloric intake decreased also within the trial. Hence, it was concluded that Zone diet is not suitable for athletes aiming to improve VO_{2max} and performance time. (Jarvis et al. 2002)

2.4.2 Paleolithic diet

Paleo diet assumes that hunter-gatherer's nutrition included lean meat, fish, shellfish, fruits, vegetables, eggs and nuts, and was low in grains, dairy, refined sugars, fats and salt (Jönsson et al. 2009). Legumes are also usually excluded from Paleo diet as they are considered anti-nutrients (Mashrani et al. 2015). Paleo's goal is to mimic the nutrition in the Old Stone Age, that is 2.5–0.01 million years before present. Restrictions in foodstuffs assume that modern diseases such as cardiovascular diseases and type 2 diabetes are a result of modern food, i.e. refined fats and sugars. (Jönsson et al. 2009)

Jönsson et al. (2009) found out that Paleo successfully reduced the glycaemic control and risks for cardiovascular disease for type 2 diabetes patients. The randomised cross-over three-month study had patients (n=13) with type 2 diabetes to follow Paleo diet or diet designed for diabetes patients. The diabetes diet included whole-grain products and root vegetables, which were excluded in the Paleo diet. The glycaemic control and cardiovascular disease risk factors improved more within the Paleo group compared to the diabetes diet group. Paleo has also been stated to e.g. reduce weight, BMI and systolic blood pressure, and improve diastolic blood pressure, glucose tolerance and insulin sensitivity. (Jönsson et al. 2009)

Healthy, sedentary, non-obese but slightly overweight adults (n=9, 6 males and 3 females) benefited from Paleo diet even within a short-term period. In Frassetto et al.'s (2009) metabolically controlled study blood pressure and lipid profiles improved, insulin secretion decreased, and insulin sensitivity increased for participants in less than two weeks after replacing their usual diet to Paleo. The study did not include increases in activity levels, and no weight loss was observed during the short-term intervention. (Frassetto et al. 2009)

Systematic review of four randomised controlled trials with total of 159 participants by Manheimer et al. (2015) also found out that Paleo resulted in short-term improvements in metabolic syndrome components when comparing to other dietary recommendations used for metabolic syndrome patients worldwide. The study stated that low-carbohydrate diet together with avoidance of high-glycaemic index products, low omega-6 over omega-3 fatty acid balance and reduction of salt intake are commonly accepted to be metabolically beneficial, whereas the benefits of avoiding whole-grain and dairy is unclear. (Manheimer et al. 2015)

2.5 Finnish dietary recommendations

The Finnish dietary recommendations are based on the Nordic dietary recommendations, which have been updated every eight years since the year 1980. The recommendations are built in mind to offer a basis for all Nordic countries' national dietary recommendations. (Nordic Council of Ministers 2012) Hence, the Finnish dietary recommendations create a framework for all Finnish population on nutrition, and they are used for following up the population's nutritional status, affecting the dietary habits of the population with the help of communication, and for political and catering purposes. It must be kept in mind, that the recommendations do not necessarily suit all purposes and for all individuals directly, including athletes. (The National Nutrition Council 2014)

Finnish dietary recommendations state that carbohydrate intake should be kept between 45 and 60 E%, protein intake between 10 and 20 E% and fat intake between 25 and 40 E% (Table 5). The sources of carbohydrate should be based on wholemeal grains, vegetables, berries, and fruits. The quality of fats is also important, as the monounsaturated fats should build up to 10–20 E%, polyunsaturated fats to 5–10 E% and saturated fat below 10 E%. The amount of trans-fatty acids should be kept as low as possible. Excessive amounts of sugar and salt should also be avoided. (The National Nutrition Council 2014)

TABLE 5. Finnish dietary recommendations (The National Nutrition Council 2014).

Macronutrient	**E%**
Carbohydrate	45–60
Protein	10–20
Fat	25–40*

E% = share of total energy intake
* monounsaturated fatty acids 10-20 E% and polyunsaturated fatty acids 5–10 E% including n-3 series fatty acids at least 1 E%

Fruits and vegetables should be consumed 500 grams each day, as they create the basis for healthy nutrition. Females should eat grains six portions and males nine portions per day, and fish should be used two to three times a week. Red meat and meat products should be eaten maximum 500 grams per week, and eggs two to three pieces per week at maximum. (The National Nutrition Council 2014)

3 GOAL AND PURPOSE OF THE RESEARCH

The aim of the research was to get an overview of the dietary habits of competitive CrossFit athletes in Finland. The adequacy of energy intake compared to training volume was assessed by comparing three-day food diaries with training descriptions on those specific days. The second aim was to find out whether the athlete nutrition correlates with various dietary recommendations: recommendations for strength and power athletes (ACSM 2016), recommendations for CrossFit (Glassman 2004; Escobar et al. 2016), and Finnish dietary recommendations (The National Nutrition Council 2014).

Thirdly, the research focused on finding out the macronutrient intake: what is the macronutrient intake and proportion between carbohydrates, proteins, and fats compared to various dietary recommendations, and are there any specific diets or avoided foods that competitive CrossFit athletes favour? The research utilised both quantitative and descriptive methods.

Research questions were the following:

1. Does the training volume of the competitive level CrossFit athletes in Finland correlate with the mean estimated daily energy intake?
2. What is the daily mean estimated macronutrient proportion of carbohydrates, proteins, and fats in E% and g/kg?
3. Does the daily mean estimated macronutrient intake in E% and in g/kg correlate with the following dietary recommendations:
    a. recommendations for strength and power athletes?
    b. official dietary recommendations for CrossFit?
    c. the Finnish dietary recommendations?
4. What are the diet characteristics among competitive CrossFit athletes?

4 MATERIAL AND METHODS

The data was collected in 2017 from athletes who had competed in the largest Finnish CrossFit competitions between 2015 and 2017 or had positioned themselves to top 100 Finnish athletes in the official CrossFit world championship qualifications. The athletes (n=29) filled three-day food diary and web-based questionnaire with training backlog.

During 2015 and 2017, 163 individual males and 151 individual females have competed in the on-hand Finnish CrossFit competitions. Invitation to participate in research was sent between June and October 2017 randomly via Facebook direct messages to 75 athletes, from which 27 (36 %, 17 males and 10 females) decided to participate. Two female athletes requested to participate directly by email after hearing about the research via other sources resulting to total n=29. Hence, 59 % (n=17) of participants were males and 41 % (n=12) were females. The research sample represents 10.4 % of the total male population, and 7.9 % of the total female population.

4.1 Inclusion criteria and dietary analysis

Inclusion criteria demanded participants to have been qualified in one of the largest CrossFit competitions in Finland between 2015 and 2017 or to have reached position among the Finland's top 100 athletes in the 2016 and/or 2017 CrossFit Open competitions. The Finnish competitions included Karjalan Kovin, Unbroken and Winter War. As the qualification for the competitions and for the Finland's top 100 in the CrossFit Open require good physical performance and dedication to CrossFit, no other criteria for being allowed to take part in the research were needed. Meeting the criteria was checked from the competition ranking history from the specific competition organiser's website.

After visual inspection all questionnaire answers were adequate, and none had to be excluded from the analyses. Three participants submitted the questionnaire answers and the food diary via email due to technical problems in the web-based questionnaire. Certain self-reported dietary supplements were not available in the dietary analysis tool food database Fineli.

Hence, the macronutrient specifications were checked from the manufacturer websites and matched with the food database's most accurate dietary supplement.

Dietary recommendations are often presented as proportion of total energy (E%) or as grams per kilogram. According to ACSM (2016), recommended daily intakes for carbohydrate and protein should be shown as g/kg which enables the interpretation of the recommendations for different body sizes. Strength and power athlete dietary recommendations are based on g/kg whereas CrossFit's official dietary recommendations and Finnish dietary recommendations are based on proportion of total energy intake (E%). To enable the comparisons between all three dietary recommendations, strength and power athlete dietary recommendations were transformed into share of total energy intake (E%) for the analysis. CrossFit dietary recommendations' intake limits were adjusted to 35–45 E% in carbohydrate and to 25–35 E% in protein and fat so that the Mann-Whitney U test analysis would be useful.

A mean estimated value of carbohydrate, protein, and fat intake in grams and in kilogram of bodyweight (g/kg) was calculated based on the daily intakes of each macronutrient. Energy intake on average in kcal for each participant was also calculated as mean estimated daily values. Results are reported separately for the male and female participants, as well as combined results for the genders. The quality of macronutrients e.g. the share of saturated fatty acids were not analysed.

4.2 Research methods

The data was collected between 29th June and 15th October 2017. First participant recruitment round was conducted in June 2017, and the questionnaire was re-opened for new responses in August 2017 as the first round in June 2017 did not reach its goal with 30 respondents (Table 6). Participants recorded the food diary and the training backlog for three days. They could choose the recording days by themselves, and whether the recordings were done on consecutive days or not.

All participants received written instructions on how to record all food and fluid consumed. Participants filled the food diaries on separate Microsoft Word or Excel document (Appendix 3) and attached it afterwards to the questionnaire (Appendix 4; Appendix 5) as a separate document. Questionnaire was conducted via web-based service provider JotForm, which saved the answers to the server.

Questionnaire included multiple choice, close-ended, and open-ended questions. The questionnaire constituted from 11 demographic and anthropometric questions assessing e.g. participant age, weight, training history in CrossFit, and amount of competitions in which the participant had taken part during the past three years. Questions about training program for the specific three days included the date, length of training, intensity of the exercise session, and open-ended question about the exercise description. Questions about nutrition included multiple choice questions about possible diet characteristics, and potential voluntarily avoided foodstuffs.

To guarantee high response rate, participants were informed to receive a nutrition feedback of their food diaries and training volume after submitting answers for the research. After receiving the answers, food diary data for each participant was manually transferred to Finnish food database Fineli which calculated the macro- and micronutrients and the total energy intakes. Dietary data was then extracted from Fineli in Excel for further statistical analyses in SPSS.

TABLE 6. Research process.

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Participant recruitment Jun-Aug-17	Food and training diaries received	Importing food diaries to Fineli	Exporting data from Fineli to Excel	Statistical analyses

Food diary platform used in this research was Fineli, the National Food Composition Database in Finland, and the service is provided by the Finnish National Institute for Wealth and Welfare (THL). THL is constantly updating the database with new foods and new features. Fineli includes thorough information about the foods and food products used in Finland based on the nutrient contents, and the database consists of more than 4,000 foods and 55 nutrient factors. The users can create an account to the database which allows to record and analyse food consumptions easily by proportions of carbohydrates, proteins, and fats, and on various micronutrients (Figure 5). (THL 2017)

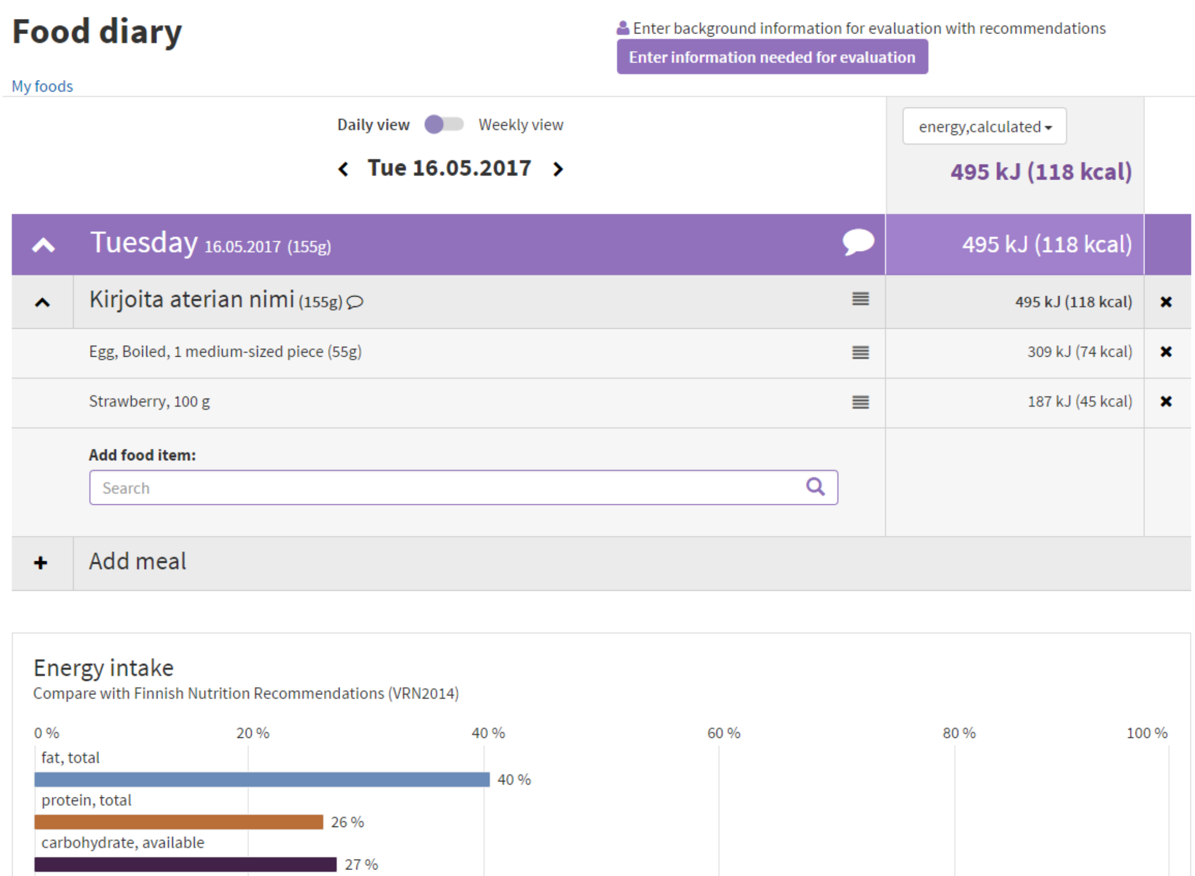

Figure 5. Overview of the food diary platform used (THL 2017).

4.3 Energy expenditure analysis

Mean estimated daily energy expenditure in kcal was calculated based on the sum of resting metabolic rate and activity energy expenditure (daily activity energy expenditure and mean estimated exercise energy expenditure) as described in chapter 2.2. Resting metabolic rate for each participant was calculated using World Health Organisation's (WHO) equation (see chapter 2.2). Daily activity energy expenditure in kcal was estimated to be between 400 and 500 kcal.

Exercise energy expenditure in kcal was estimated based on participant's daily training descriptions on length and intensity. Expenditure was once again transformed into mean estimated daily expenditure. Total exercise energy expenditure was estimated by multiplying the MET value based on the intensity of the exercise, training length in hours and the participant's body weight in kilograms. Exercise METs were based on Finnish UKK Institute's (2015) framework on exercise workload. E.g. 9 MET exercise for 120 minutes training for participant who weighs 70 kg equals to 1,260 kcal energy expenditure. Each participant's mean estimated energy balance was then calculated by deducting mean estimated energy expenditure from mean estimated energy intake in kcal.

4.4 Statistical analysis

Statistical analyses were performed using IBM SPSS version 24 (Armonk, NY, USA). Normal distribution was tested with Kolmogorov-Smirnov test, which was essential for Spearman and Pearson correlation analyses. Mann-Whitney U test was utilised for variables that did not fill the requirements for normal distribution: age ($p=0.017$), weight ($p=0.008$), training history in CrossFit ($p<0.001$), mean estimated carbohydrates per weight ($p=0.001$), and daily basic metabolic rate ($p<0.001$). One-way ANOVA and Pearson correlation analyses were also performed. The food diaries were analysed based on the Finnish food database Fineli.

Mann-Whitney U test was used for analysing potential differences between participants, whose macronutrient intake was in line with the dietary recommendations whether in relation to strength and power athlete recommendations, CrossFit dietary recommendations, or Finnish dietary recommendations. For analysis, the participants were divided into two groups: those who followed the recommendations and to those who did not. The distribution of age, weight, height, training history in CrossFit, weekly training volume, daily energy intake, daily energy expenditure, and daily energy balance were then analysed. Statistical differences in the mentioned variables were observed in case $p<0.05$.

Body mass index (BMI) (kg/m^2) was calculated from the participants' self-reported body weight and height. In addition, macronutrient intake in grams per kilogram of body weight per day (g/kg) and energy intake in kilocalories per kg of bodyweight (kcal/kg) were calculated based on the participants' self-reported weight.

5 RESULTS

5.1 Participants

Table 7 presents the participant characteristics. Participants consist of 22 to 47-year-old males and females (mean 29.3 years ±5.9). 21 % (n=6) of the participants were 20–24 years old, 41 % (n=12) were 25–29 years old, 24 % (n=7) were 30–34 years old and 14 % (n=4) were 35 years or older. For males, the mean age was 29 years, and for females 30 years.

TABLE 7. Participant characteristics.

Variable	All		Males		Females		p-value[a]
n (%)	29 (100.0)		17 (58.6)		12 (41.4)		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Age, yrs (SD)	29.3	5.9	28.9	5.4	30.0	6.8	0.626
20–24 yrs (%)	6 (21)		4 (24)		2 (17)		
25–29 yrs (%)	12 (41)		7 (41)		5 (42)		
30–34 yrs (%)	7 (24)		4 (24)		3 (25)		
≥35 yrs (%)	4 (14)		2 (12)		2 (17)		
Height, cm	174.8	7.4	179.8	5.0	167.8	3.4	0.000
Weight, kg	79.5	11.8	88.5	5.6	66.7	2.4	0.000
BMI, kg/m^2	25.9	2.2	27.4	1.3	23.7	1.1	0.000
Training history, yrs[b]	4.4	1.4	4.5	1.4	4.3	1.3	0.592
Training volume, h[c]	12.5	3.7	11.5	3.9	14.0	3.2	0.090
Ranking[d]	13th	7.5	14th	7.5	12th	7.7	0.356
Amount of competitions[e]	4.2	1.6	4.1	1.7	4.4	1.6	0.633

Yrs=years, SD=Standard deviation
[a]One-way ANOVA, between males and females, [b]Overall training history within CrossFit, [c]Weekly training volume, [d]Ranking in competitions(s) during 2015-2017 in Karjalan Kovin and/or Unbroken and/or Winter War, [e]The amount of competition experience in the following competitions during 2015-2017: Karjalan Kovin and/or Unbroken and/or Winter War

Participants' body weight was on average 79.5 ±11.8 kilograms whereas height was 174.8 ±7.4 cm on average. For 62 % (n=18) of participants the BMI was above 25 kg/m^2, and the mean BMI was 25.9 ±2.2 kg/m^2. All males (n=17) had BMI above 25 kg/m^2, whereas only one woman had BMI over 25 kg/m^2. Participants had been training CrossFit on average for 4.4 ±1.4 years. Mean weekly training volume was 12.5 ±3.7 hours. Average ranking in

Karjalan Kovin and/or Unbroken and/or Winter War between 2015 and 2017 was 13th (±7.5) position.

When comparing genders, females were 1.1 years older on average compared to males. Females' BMI was 3.7 kg/m^2 lower than for males, and they also trained 2.5 hours more than males. Average ranking for male athletes was 14th position and for females 12th position. Between genders, statistically significant differences were found in body mass ($p<0.001$), height ($p<0.001$), and BMI ($p<0.001$) as males had larger body mass and were taller.

No statistically significant differences were found in age ($p=0.626$), weekly training volume ($p=0.090$), training history ($p=0.592$), nor in ranking in competitions ($p=0.356$) between genders. On average, the participants had taken part in 4.2 competitions, males to 4.1 and females to 4.4 competitions ($p=0.633$). 90 % (n=26) of participants had experience of other sports before starting CrossFit (Table 8). 10 % (n=3) of participants reported currently to be doing other sports besides CrossFit, such as running or swimming.

TABLE 8. Previous sports done before CrossFit.

Sports	**n**	**%**	
Ice hockey	3	10.3	
Gymnastics	3	10.3	total
Boxing	2	6.8	89.7 %
Other sports	18	62.1	
None	3	10.3	

5.2 Training volume compared with the daily mean estimated energy intake

There was a statistically significant difference in the mean estimated daily energy intake between males and females ($p=0.002$) (Table 9). The mean estimated daily energy intake was 3,593 kcal (±727) for males and 2,709 kcal (±574) for females. Overall, the mean estimated daily energy intake was 3,228 kcal (±792) for males and females.

A statistically significant difference was found in the mean estimated daily energy expenditure between males and females ($p=0.001$). The mean estimated daily energy expenditure was 3,610 kcal (±623) for males and 2,867 kcal (±338) for females, whereas for both genders' mean estimated energy expenditure resulted to 3,302 (±637) kcal.

As seen in Table 9, the mean estimated energy intake was in balance for both genders. Males met the energy balance on average, whereas for females there was an -6 % imbalance on average. The mean estimated daily energy balance in kcal was slightly negative (-13 kcal, ±873) for males, whereas the balance was more negative for females (-158 kcal, ±545). The combined mean estimated daily energy balance for both genders was slightly negative (-72 kcal, ±746). The difference between the mean estimated energy balance between genders was not statistically significant (p=0.617).

TABLE 9. Mean estimated daily energy intake, energy expenditure and energy balance in kcal.

Variable	**All**		**Males**		**Females**		**p-value**[a]
n (%)	29 (100.0)		17 (58.6)		12 (41.4)		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
in kcal							
Energy intake	3,228	792	3,593	727	2,709	574	0.002
Energy expenditure	-3,302	637	-3,610	623	-2,867	338	0.001
Energy balance	-72	746	-13	873	-158	545	0.617
Energy balance (%)	0.0		0.0		-5.5		

SD=Standard deviation
[a]One-way ANOVA, between males and females

There was a statistically significant negative correlation ($r=-0.389$, $r^2=0.15$) between the weekly training volume in hours and the mean estimated daily energy balance in kcal (p=0.037). No statistically significant correlations were found (r=0.033) in the Pearson correlation test between the average ranking in competitions and mean estimated daily energy supply in kcal (p=0.867) nor between the average ranking in competitions and weekly training amount in hours (p=0.274). No statistically significant correlations were found between the average ranking in competitions and mean estimated daily intake of carbohydrates, proteins, and fats in g/kg and in E%. P-values in g/kg were p=0.855, p=0.069, p=0.473 and in E% p=0.946, p=0.121, p=0.337, respectively.

No statistically significant correlations were found between the amount of the training and energy intake. Pearson correlation test showed that the correlation between the weekly training volume in hours and mean estimated daily energy intake in kcal was negative for -

0.204, but it was not statistically significant (p=0.288). In addition, regression analysis showed no high level of correlation between the weekly training volume and the mean estimated daily energy intake (r^2=0.006, p=0.288). When the weekly training volume increased by one hour, mean estimated daily energy intake decreased by 0.001 kcal.

5.3 Daily mean estimated macronutrient proportion in E% and in g/kg

The mean estimated carbohydrate intake was 4.2 g/kg, protein intake 2.5 g/kg and fat intake 1.5 g/kg. For males, the mean estimated carbohydrate intake 4.1 g/kg, protein intake 2.5 g/kg, and fat intake 1.6 g/kg (Table 10). For females, the mean estimated carbohydrate intake was 4.4 g/kg, protein intake 2.4 g/kg, and fat intake 1.5 g/kg. When analysing the participants' food diary data for the macronutrient intake by body mass (g/kg), no statistically significant differences were found between genders in carbohydrate (p=0.444), protein (p=0.603) nor in fat intake (p=0.469).

TABLE 10. Mean estimated macronutrient proportion in g/kg and in E%.

Variable	**All**		**Males**		**Females**		**p-value**[a]
n (%)	29 (100.0)		17 (58.6)		12 (41.4)		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
in g/kg							
Carbohydrate	4.2	1.2	4.1	1.1	4.4	1.3	0.444
Protein	2.5	0.5	2.5	0.5	2.4	0.6	0.603
Fat	1.5	0.4	1.6	0.4	1.5	0.4	0.469
in E%							
Carbohydrate	41.3	6.2	40.1	6.1	43.0	6.2	0.221
Protein	26.0	5.1	25.8	4.3	26.3	6.2	0.768
Fat	33.8	7.1	34.6	6.5	32.6	7.9	0.454

g/kg=Macronutrients per body weight in kilograms, E%=Share of total energy intake, SD=Standard deviation

The mean estimated intake of carbohydrate, proteins and fat was 41 E%, 26 E%, and 34 E%, respectively (Table 10). The mean estimated carbohydrate intake for males provided 40 E%, protein intake 26 E%, and fat intake 35 E%. For females the mean estimated carbohydrate intake provided 43 E%, protein intake 26 E%, and fat intake 33 E%. Again, no statistically significant differences were found between genders in carbohydrate intake in E% (p=0.221), protein intake (p=0.768) nor in fat intake (p=0.454).

5.4 Daily mean estimated macronutrient proportion compared to dietary recommendations

Table 11 shows the participants' macronutrient intakes and the recommended intakes based on the dietary recommendations.

TABLE 11. Macronutrient intake in E% - Summary of dietary recommendations and mean estimated intakes in E% (Glassman 2004; McArdle et al. 2010; The National Nutrition Council 2014).

Dietary recommendations in E%			
Dietary recommendation	**Carbohydrate**	**Protein**	**Fat**
Finnish nutrition DR	45–60	10–20	25–40*
Strength and power athlete DR	50–70	20–30*	30–45*
CrossFit DR	40*[a]	30*[b]	30*[c]
Mean estimated intake in E%			
Gender	**Carbohydrate**	**Protein**	**Fat**
Males (n=17)	40	26	35
Females (n=12)	43	26	33
All (n=29)	41	26	34

*Mean estimated intakes for both males and females were within the specific dietary recommendation, E%=Share of total energy intake, DR=Dietary recommendation
[a]Carbohydrate intake recommendation cut-off set to 35–45 E%, [b]Protein intake recommendation cut-off set to 25–35 E% [c]Fat intake recommendation cut-off set to 25–35 E%

5.4.1 Carbohydrate intake compared to dietary recommendations

Neither males nor females met the lower range of daily carbohydrate intake of the Finnish dietary recommendations and of the dietary recommendations for strength and power athletes (Table 11 above). The mean estimated macronutrient intake was close to the official CrossFit dietary recommendations' carbohydrate intake of 40 E% in relation to the cut-off limits. For 14 % (n=4) of participants the carbohydrate intake was within the dietary recommendations for strength and power athletes (50–70 E%), and for 31 % (n=9) of participants the carbohydrate intake was within the Finnish dietary recommendations range of 45–60 E%. For 59 % (n=17) of participants the carbohydrate intake was in line with the official CrossFit dietary recommendations.

When comparing participants who met the strength and power athlete recommendations in carbohydrate, a statistically significant difference was found in the distribution of age and carbohydrate intake (p=0.006) in Mann-Whitney U test (Table 12). Participants who met the carbohydrate intake recommendations were younger compared to participants whose intake was below 50 E% (86 %, n=25).

TABLE 12. Characteristics of the study population based on their dietary habits and strength and power athlete recommendations in E%.

Carbohydrate intake	**SPR: 50–70 E%**	**<50 or >70 E%**	**p-value[a]**
Age, yrs	24.0	30.2	0.006
Height, cm	171.5	175.3	0.341
Weight, kg	71.2	80.8	0.142
Training history, yrs[b]	3.5	4.6	0.109
Training volume, h[c]	13.5	12.4	0.784
Energy intake, kcal	3,049	3,256	0.482
Energy expenditure, kcal	-3,187	-3,321	0.692
Energy balance, kcal	-139	-62	1.000
Protein intake	**SPR: 20–30 E%**	**<20 or >30 E%**	**p-value[a]**
Age, yrs	30.0	26.7	0.254
Height, cm	175.8	171.0	0.192
Weight, kg	80.2	76.7	0.445
Training history, yrs[b]	4.3	4.8	0.445
Training volume, h[c]	12.4	12.8	0.733
Energy intake, kcal	3,347	2,770	0.142
Energy expenditure, kcal	-3,371	-3,040	0.328
Energy balance (kcal)	-21	-270	0.384
Fat intake	**SPR: 30–45 E%**	**<30 or >45 E%**	**p-value[a]**
Age, yrs	29.5	29.2	0.475
Height, cm	177.4	171.5	0.032
Weight, kg	84.3	73.5	0.032
Training history, yrs[b]	4.6	4.2	0.531
Training volume, h[c]	10.9	14.5	0.007
Energy intake, kcal	3,289	3,152	0.475
Energy expenditure, kcal	-3,324	-3,275	0.682
Energy balance, kcal	-31	-124	0.812

E%=Share of total energy intake, SPR=Strength and power athlete dietary recommendations
[a]Mann-Whitney U test, [b]Overall training history within CrossFit, [c]Weekly training volume

5.4.2 Protein intake compared to dietary recommendations

Both genders met the protein intake of dietary recommendation for strength and power athletes (20–30 E%): protein intake was 26 E% for males and females. Protein intake was lower compared to the official CrossFit dietary recommendation of 30 E%, but me the cut-off points of 25–35 E%. On the other hand, protein intake was above the Finnish dietary recommendations for both genders. 10 % (n=3) of participants met the Finnish dietary recommendations' protein intake, whereas for 90 % (n=26) of participants intake was above 20 E%. For 79 % (n=23) of participants the protein intake was in line with the dietary recommendations for strength and power athletes. For 55 % (n=16) of participants the protein intake met the official CrossFit dietary recommendations.

5.4.3 Fat intake compared to dietary recommendations

Fat intake (34 E%) was in line with strength and power athlete dietary recommendations (30–45 E%). For males and females, the fat intake was 35 E% and 34 E%, respectively. For 55 % (n=16) of participants the fat intake resembled the dietary recommendations for strength and power athletes. Mann-Whitney U test showed statistically significant difference in the distribution of participant height and fat intake (p=0.032) and with weight and fat intake (p=0.032) in relation to dietary recommendations for strength and power athletes (Table 12). Participants who met the fat intake recommendations (55 %, n=16) were taller and had larger body weight than participants whose fat intake was below 30 E% or above 45 E% (45 %, n=13). For 38 % (n=11) of participants the fat intake was below the recommendations, and for 7 % (n=2) of participants above the recommendations.

Also, there was a statistically significant difference in the distribution of weekly training volume and fat intake (p=0.007) in relation to dietary recommendations for strength and power athletes. Participants who trained less were more likely to meet the fat intake recommendations compared to participants who trained more weekly. No differences were observed in other variables between the participants compared to the strength and power athlete recommendations.

Mean estimated daily fat intake was within the official CrossFit dietary recommendations as it met the cut-off limits of 25-35 E%. Mann-Whitney U test showed statistically significant difference in the distribution of participant age and fat intake ($p=0.05$) in relation to the CrossFit official dietary recommendations (Table 13). Participants, whose fat intake was in line with the recommendations (55 %, n=16), were younger compared to participants who did not meet the recommendation (45 %, n=13). For 41 % (n=12) of participants the fat intake was above recommendations, and for 3 % (n=1) of participants the fat intake was below the recommendations. No differences were observed in the other variables compared to participants' fat intake in relation to the official CrossFit dietary recommendations. For 55 % (n=16) of participants the fat intake resembled the official CrossFit dietary recommendations.

TABLE 13. Characteristics of the study population based on their dietary habits and CrossFit dietary recommendations in E%.

Carbohydrate intake[a]	**CFR: 35–45 E%**	**<35 or >45 E%**	**p-value**[b]
Age, yrs	29.5	29.1	0.616
Height, cm	173.6	176.5	0.347
Weight, kg	77.7	82.0	0.303
Training history, yrs[c]	4.5	4.3	0.744
Weekly training volume, h	12.9	11.9	0.471
Energy intake, kcal	3,079	3,438	0.325
Energy expenditure, kcal	-3,188	-3,465	0.370
Energy balance, kcal	-105	-27	0.471
Protein intake[d]	**CFR: 25–35 E%**	**<25 or >35 E%**	**p-value**[b]
Age, yrs	30.2	28.3	0.746
Height, cm	175.1	174.5	0.812
Weight, kg	79.5	79.4	0.812
Training history, yrs[c]	4.3	4.6	0.746
Weekly training volume, h	12.8	12.2	0.846
Energy intake, kcal	3,298	3,142	0.650
Energy expenditure, kcal	-3,334	-3,264	0.846
Energy balance, kcal	-32	-122	0.983
Fat intake[e]	**CFR: 25–35 E%**	**<25 or >35 E%**	**p-value**[b]
Age, yrs	28.2	30.8	0.050
Height, cm	174.4	175.2	0.846
Weight, kg	78.3	80.9	0.619
Training history, yrs[c]	4.3	4.5	0.619
Weekly training volume, h	13.2	11.7	0.475
Energy intake, kcal	3,279	3,165	0.812
Energy expenditure, kcal	-3,388	-3,197	0.682
Energy balance, kcal	-104	-33	0.682

E%=Share of total energy intake, CFR=CrossFit dietary recommendations
[b]Carbohydrate intake recommendation cut-off set to 35–45 E%, [b]Mann-Whitney U test [c]Overall training history within CrossFit,
[d]Protein intake recommendation cut-off set to 25–35 E% [e]Fat intake recommendation cut-off set to 25–35 E%

Fat intake was in line with the Finnish dietary recommendations for both genders. 28 % (n=8) of participants did not meet the fat intake recommendations (25–40 E%), whereas 72 % (n=21) of participants met the recommendations. Statistically significant difference was found in the distribution of participant age and fat intake (p=0.018) in relation to Finnish dietary recommendations (Table 14). Participants, whose fat intake was in line with the recommendations (72 %, n=21), were younger compared to participants whose fat intake as above the recommendations (28 %, n=8). No differences were observed in the other variables compared to participants' macronutrient intakes in relation to Finnish dietary recommendations.

TABLE 14. Characteristics of the study population based on their dietary habits and Finnish dietary recommendations in E%.

Carbohydrate intake	**FDR: 45–60 E%**	**<45 or >60 E%**	**p-value[a]**
Age, yrs	28.9	29.6	0.216
Height, cm	174	175	0.694
Weight, kg	77.1	81.0	0.660
Training history, yrs[b]	4.2	4.5	0.532
Weekly training volume, h	13.6	12.1	0.472
Energy intake, kcal	3,483	3,113	0.417
Energy expenditure, kcal	-3,513	-3,208	0.295
Energy balance, kcal	-31	-91.5	0.660
Protein intake	**FDR: 10–20 E%**	**<10 or >20 E%**	**p-value[a]**
Age, yrs	27.0	29.6	0.563
Height, cm	172	175	0.429
Weight, kg	76.7	79.8	0.973
Training history, yrs[b]	4.0	4.5	0.710
Weekly training volume, h	13.7	12.4	0.516
Energy intake, kcal	3,035	3,250	0.660
Energy expenditure, kcal	-3,057	-3,331	0.563
Energy balance, kcal	-23	-78	0.563
Fat intake	**FDR: 25–40 E%**	**<25 or >40 E%**	**p-value[a]**
Age, yrs	28.1	32.6	0.018
Height, cm	174	176	0.518
Weight, kg	78.6	81.8	0.487
Training history, yrs[b]	4.4	4.5	0.720
Weekly training volume, h	13.0	11.4	0.549
Energy intake, kcal	3,166	3,390	0.401
Energy expenditure, kcal	-3,344	-3,194	0.756
Energy balance, kcal	-174	194	0.237

E%=Share of total energy intake, FDR=Finnish dietary recommendations,
[a]Mann-Whitney U test, [b]Overall training history within CrossFit

5.5 Diet characteristics among competitive CrossFit athletes

When inquiring about special diets, 76 % (n=21) reported not to be following any special diets, 10 % (n=3) followed Paleo diet, 7 % (n=2) reported gluten-free diets, 7 % (n=2) did not use dairy products, and 3 % (n=1) of participants reported to be following low-lactose diet (Table 15). 10 % (n=3) of participants had food allergies, whereas 41 % (n=12) of participants avoided voluntarily one or more foodstuffs: 24 % avoided (n=7) dairy, 14 % (n=4) avoided gluten, 10 % (n=3) avoided added sugar, 7 % (n=2) avoided grains, and 29 % (n=7) avoided other foods (Table 16). 7 % (n=2) of participants reported to be following gluten-free diet, and 14 % (n=4) of participants reported to be avoiding gluten voluntarily as a foodstuff.

TABLE 15. Reported special diets.

Special diet	**Yes**	**No**	**Total**
Special diet	8	21	29
Paleo	3		
Gluten-free	2		
No dairy	2		
Low-lactose	1		

No one reported to be following Zone diet, and 10 % (n=3) of participants reported to be following Paleo diet. In addition, there were more participants who seemed to be following Paleo diet recommendations at least on some level, as the avoidance of dairy, added sugar, grains, and legumes was mentioned in the questionnaire answers.

TABLE 16. Voluntarily avoided foodstuff.

Special diet	**Yes**	**No**	**Total**
Food allergies	3	26	29
Avoids foodstuff	12	17	29
Avoided foodstuff	**n[a]**	**%**	
Dairy*	7	24.1	
Gluten	4	13.8	
Added sugar*	3	10.3	
Grain*	2	6.9	
Curd	1	3.4	
Fish	1	3.4	
Legumes*	1	3.4	
Onion	1	3.4	
Red meat	1	3.4	
Starch	1	3.4	

*Paleo diet suggests avoiding these ingredients

[a]Each participant could avoid one or more foodstuffs voluntarily

6 CONCLUSIONS

Research conducted worldwide on nutrition and CrossFit is limited to-date, and nutrition of Finnish competitive CrossFit athletes has not been studied at all. Previous studies agree that high-carbohydrate nutrition improves exercise performance. On the other hand, CrossFit community favours low-carbohydrate intake, and Paleo and Zone diets are exploited to provide directive for such nutrition.

The aim of this research was to gain an overlook on competitive CrossFit athletes' nutrition in Finland especially on macronutrient level, and whether the diets are following the on-hand dietary recommendations: Finnish dietary recommendations, strength and power athlete dietary recommendations, and official CrossFit dietary recommendations. The goal was to also find out potential connection with the athletes' energy balance and the performance development, i.e. assess the adequacy of the macronutrient intake in relation to the training volume. Information on dietary habits and training volume was gathered via web-based questionnaire and three-day food diary.

Competitive CrossFit athletes' intake on carbohydrate is inadequate in relation to strength and power athlete recommendations, but adequate in relation to CrossFit recommendations. Protein intake met strength and power athlete recommendations and CrossFit recommendations, and mean estimated fat intake was within all dietary recommendations. Younger athletes were more likely to meet the carbohydrate intake of strength and power athlete recommendations, and the fat intake of the Finnish recommendations and of CrossFit recommendations. Athletes should be aware that increase in training volume may result in decrease in energy balance and in fat intake.

6.1 Reliability of the research

Invitation to participate was sent via Facebook direct messages to total of 75 athletes, from whom 36 % (n=27) decided to join the research. Two athletes requested to join the research directly via email, resulting to n=29. Total of 48 athletes (64 %) declined their involvement or left the invitation message unanswered.

Reasons for participation refusal are unknown. Nevertheless, the refusals not to participate did not affect the analysis as the targeted sample population was set to 30 participants, and the research sample consist of 29 participants. However, issue considering the refusals is associated to a potential common factor connecting the declined athletes not present in the current sample population. This results to potential limiting factor in generalisation of the results. (Metsämuuronen 2011) Potential missing information may be related to macronutrient proportion in diet or dissimilar energy intake compared to the research sample. Moreover, athletes who decided to participate may obtain better awareness on health and nutrition compared to refused athletes, especially as the participants had the possibility to receive nutrition feedback of their food diaries and training volume after submitting answers for the research.

Both genders were relatively evenly present in the research sample, as total of 17 males (59 %) and 12 females (41 %) decided to join the research. Comparisons between males and females as well as combined assessments between the characteristics of both genders were conducted. Previous studies indicate seasonal differences between genders in food intake e.g. within fruits, vegetables and eggs (Rossato and Fuchs 2014). In Hinton et al.'s (2005) study, for males the low-level of carbohydrate intake was due to disordered eating patterns, and for females the reason was a desire to lose weight, whereas for individuals without such issues the carbohydrate intake was adequate. In this research it is not clear if such issues affected the results e.g. in relation to the low-level of carbohydrate intake.

Limitations of this research are related to the data collection method, as information on energy intake was collected via self-reported three-day food diaries. Self-reported energy intakes have been noted to be inadequate within Canadian athletes (Lun et al. 2009). Nevertheless, food diaries are widely used for assessing macronutrient intake, although underreporting is an issue always to be considered, as it is a well-known possibility for bias in nutrition studies (Reed et al. 2013).

The advantage in food diaries as a research method is its level of detail, and that it focuses on the *current* diet (Lovegrove et al. 2015). Therefore, the connection e.g. with gained position in specific competition in the past and the energy balance or macronutrient proportion in the current diet must be analysed with provision, as intra-individual variability in diets may affect the food intake in different time periods. Also, although such potential provisions relating to the generalisation would not exist, it does not guarantee accurate nutrition presented by the data as the participant may modify one's diet for the research period e.g. by choosing different foods, or consuming different amounts than usually.

Significance of this research would have increased with a larger sample population and longer food diary reporting period. Requiring pictures of food portions in addition to the food diaries could have decreased the potential risk for underreporting. The risk for dietary habit modifications is always present in nutritional descriptive research, and for this research possible changes remain unclear. As the reported energy intake resulted in negative energy balance for many individual participants, it can be questioned and assessed whether it is a result of underreporting. Still, as the mean estimated energy intake and expenditure were in balance, possibility for underreporting is decreased within the overall sample population. Similarly, only three participants reported any alcohol use during the reporting period, which must be considered as potential underreporting occurrence within all the other participants.

Statistical analyses were based on Pearson correlation and Mann-Whitney U tests (IBM SPSS 24), which were suitable for this research, as the research sample was below 30 participants and the data included primarily scale variables. When importing food diary data to the food diary platform Fineli, some assumptions were made as in some cases the reported food amount was e.g. "large portion" or "half a plate". Fineli had a possibility to submit information in grams in addition to dropdown menus with e.g. "large portion", and therefore the equivalency between the participant's and Fineli's interpretation of such magnitudes is unknown. The following analyses are based on estimates on the energy intake and energy expenditure based on the reported food diaries and descriptions on exercises as well as on participant characteristics.

6.2 Results

It is widely believed within the CrossFit community that Paleo and Zone diets provide the optimum nutrition for CrossFit (Escobar et al. 2016). In this study, none of the participants reported to be following Zone diet, and few followed Paleo diet. Despite this, the dietary habits of the participants resembled the CrossFit dietary recommendations. Most importantly, macronutrient intakes were relatively in line with the CrossFit dietary recommendations. In addition, some participants seemed to be following Paleo diet at least on some level, as they reported the avoidance of dairy, sugar, grains, and legumes.

Only few participants reported to be following gluten-free diet, and some reported to be avoiding gluten voluntarily as a separate foodstuff. The difference in the way of reporting the gluten-free diet probably due to awareness of each special diet, and to the questionnaire structure.

Younger participants' fat intake resembled the Finnish dietary recommendations. On the contrary, Ruiz et al. (2005) did not find differences in fat nor in protein intake between younger (adolescent) and older (adult) soccer player athletes. However, as fat provides the most calories per gram, it may grant one explanation on the fact that the caloric intake was adequate for the younger soccer players compared to the older athletes. If this is the case, it may provide some support also for this research's results.

In Ruiz et al. (2005) research the energy intake per body weight in kilograms was higher for adolescent soccer player athletes compared to adult players. For adult athletes the carbohydrate intake was lower and did not meet the recommendations, whereas for adolescents the intake was adequate. (Ruiz et al. 2005) Results are in line with this research, as for younger participants the carbohydrate intake resembled the strength and power athlete dietary recommendations. Also, younger participants met the CrossFit dietary recommendations in relation to fat intake.

Ruiz et al. (2005) suggested that adolescent athletes have more balanced diet due to school meals, whereas adults do not necessarily have such consistent and systematic schedule on meals. In this research all participants were adults. Anyway, for some participants the daily routines may include having lunch at workplace or school (e.g. at university) canteen, whereas others may perform meal prepping by themselves. This may provide an explanation on the difference in carbohydrate and fat intake based on the participant age, however information on the source of the meals was not available in this research.

Participant height and weight was associated with fat intake being in line with strength and power athlete dietary recommendations. The connection might be explained by gender, although Min et al. (2014) did not find differences between females and males in accordance to fat intake of healthy non-athlete Norwegians. Still, high-fat diet, i.e. 35 E%, has been associated with higher BMI compared to moderate- (28 E%) and low-fat diets (20 E%) within adult Mexican Americans (Black et al. 2013).

This research gave indications that increase in weekly training volume may lead to energy imbalance for competitive CrossFit athletes in addition to the fact that increase in training volume is associated with lower levels of fat intake. As fat provides the most calories and energy per gram, fat intake and energy intake are most likely connected. Earlier studies have also indicated that two-day aerobic exercise (Douglas et al. 2014) did not change appetite in relation to carbohydrate and in fat intake, and that 60-minute swimming session did not change carbohydrate, protein nor fat intake post-exercise (King et al. 2011). As seen here, increase in training volume may not enhance appetite for specific macronutrients or calories in general.

A statistically significant difference was found in the mean estimated daily energy intake, and in the mean estimated daily energy expenditure. The mean estimated daily energy balance was zero for both genders: Males were in energy balance on average, whereas for females there was an imbalance of -6 % in energy. Earlier studies indicate that inadequate energy intake is common among athletes (Ruiz et al. 2005; Wierniuk and Wlodarek 2013; Naughton et al. 2016) Drenowatz et al.'s (2012) study proposed that underreporting occurred in relation to caloric intake for endurance male athletes, which may have resulted to energy imbalance compared to dietary recommendations.

6.3 Conclusions and further research topics

When comparing the macronutrient intakes and the dietary recommendations, it is evident that competitive CrossFit athletes' diets cannot be characterised with only one of the on-hand dietary recommendations. As previous studies on CrossFit nutrition have focused mainly on nutritional supplements, research-based evidence on the most optimum nutrition is lacking. CrossFit nutrition does not provide macronutrient guidelines on g/kg. As a result, diet characterised with inadequate energy intake may still meet the macronutrient intake guidelines in E% of daily energy intake. Also, in case of excessive energy intake the macronutrient intake may be large in g/kg.

The athletes' diets got closest to the strength and power athlete dietary recommendations, as only carbohydrate intake was not in line with the recommendations. The actual macronutrient proportions were also relatively close to the CrossFit recommendations after setting analysis cut-points (e.g. recommendation for carbohydrate intake 40 E% -> cut-point to 35-45 E%). Out of the various macronutrients, carbohydrate intake was the closest to CrossFit dietary recommendations.

Low-level carbohydrate intake was a common feature within the sample population. and diets resembled the anecdotal diet encouraged within the CrossFit community. In Wierniuk's and Wlodarek's (2013) study the diet of male endurance athletes was too high in fat and protein, and Naughton et al.'s (2016) study suggested that carbohydrate intake was too low for soccer player athletes, who should aim to carbohydrate intake of 6–10 g/kg according to previous studies conducted within the sports.

CrossFit's nature as high-intensity cardiorespiratory sports and the demand for the athlete to maintain maximal power are without questioning indispensable features for competitive athletes in the sports. Hence, it can be questioned if the high-performers in CrossFit benefit from nutrition that is beyond the generally accepted dietary recommendations. Further research is warranted in finding possible performance differences between groups of low- and high-level of carbohydrate intake, and whether low-carbohydrate intake has positive or negative effects on the performance in CrossFit.

The CrossFit philosophy states that nutrition creates prerequisite for the overall performance development (Glassman 2002). This assumption is in line with the research to-date, as high-quality nutrition is essential in addition to long-term training and adequate rest for performance development (Ilander 2014a; Slater and Phillips 2011). As such, no discrepancies exist within the CrossFit philosophy and research to-date, but *how* to precisely construct the optimum nutrition is under debate.

This research focused on creating an overall picture of the dietary habits of competitive CrossFit athletes in Finland. As CrossFit is a relatively young sport, diversities in nutrition best practices have come into existence. As research to-date does not entirely agree on the nutrition required for success in CrossFit, unawareness and uncertainty may occur about the best practices to implement in relation to e.g. improve performance. Therefore, more academic research is warranted for finding the optimum nutrition for CrossFit. Meanwhile it is encouraged to apply previous research-based practices with small adjustments, e.g. implementing the strength and power athlete dietary recommendations to CrossFit athlete’s diet.

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APPENDICES

Appendix 1. Official CrossFit affiliates in Finland, March 2017
(CrossFit.com 2017c).

CrossFit 10K
CrossFit 33400
CrossFit 40100
CrossFit 60100
CrossFit 8000
CrossFit Basement
CrossFit Basement Kurvi
CrossFit Central Helsinki
CrossFit Central NLA
CrossFit East Turku
CrossFit Espoo
CrossFit Herttoniemi
CrossFit Huntti
CrossFit Hyvinkää
CrossFit Härkä
CrossFit Ilves
CrossFit Imatra
CrossFit Jeppis
CrossFit Jyväskylä
CrossFit Järvenpää
CrossFit Kauhava
CrossFit Kerava
CrossFit Kehä
CrossFit Kirkkonummi
CrossFit Kokkola
CrossFit Kuopio
CrossFit Kuusankoski
CrossFit Lahti
CrossFit Lappeenranta Varikko
CrossFit Lapua
CrossFit Lauttasaari
CrossFit Lohja
CrossFit Loviisa
CrossFit Mikkeli
CrossFit Myrsky
CrossFit Naantali
CrossFit Nuijala
CrossFit North AX
CrossFit Oulu
CrossFit Paja
CrossFit Pieksämäki
CrossFit Pori
CrossFit Porvoo
CrossFit Raisio
CrossFit Rauma
CrossFit Routa
CrossFit SLN
CrossFit Seinäjoki
CrossFit Siilinjärvi
CrossFit SixtyFive100
CrossFit Svartbox
CrossFit Sörnäinen
CrossFit Takomo
CrossFit Tampere
CrossFit Tuusula
CrossFit Vantaa
CrossFit Varasto
Eagle Town CrossFit
North Engine CrossFit
Reebok CrossFit Turku
Reebok CrossFit 33100
SantaSport CrossFit
Stadi CrossFit

Appendix 2. Examples of CrossFit WODs (Glassman 2002).

Fran – 3 rounds, 21–15–9 reps for time:

- 43 kg thruster
- Pull-ups

Murph – for time:

- 1-mile run
- 100 pull-ups
- 200 push-ups
- 300 squats
- 1-mile run

DT - five rounds for time:

- 12 deadlifts 70 kg
- 9 hang power cleans 70 kg
- 6 push jerks 70 kg

Filthy 50 – for time:

- 50 box jumps, 24-inch box
- 50 jumping pull-ups
- 50 kettlebell swings, 16 kg
- 50 steps walking lunges
- 50 knees to elbows
- 50 push press, 45 pounds
- 50 back extensions
- 50 wall ball shots, 9 kg ball
- 50 burpees
- 50 double-unders

Appendix 3. Food diary templates in Finnish and in English.

[LATAA TIEDOSTO: KLIKKAA IKKUNAN OIKEASSA YLÄKULMASSA OLEVISTA KOLMESTA PISTEESTÄ -> "LATAA/DOWNLOAD"]

RUOKAPÄIVÄKIRJA

Pidä ruokapäiväkirjaa kolme vuorokautta (ei välttämättä peräkkäisiä päiviä). Kirjaa kaikki nauttimasi ruoat ja juomat mahdollisimman tarkasti heti syötyäsi, mikäli mahdollista. Ole rehellinen, älä muuta tottumuksiasi ruokapäiväkirjan täyttämisen vuoksi. Jos mahdollista, kirjaa ylös myös kaikki käyttämäsi lisäravinteet.

Ruokapäiväkirja palautetaan kyselyn (https://form.jotformeu.com/71572116273352) **kautta liitetiedostona**. Voit tehdä ruokapäiväkirjan tässä tiedostossa (sivut 1-3) olevan mallin mukaisesti, tai halutessasi jotain muuta tapaa käyttäen (esimerkiksi Terveyden ja hyvinvoinnin laitoksen ilmainen web-ruokapäiväkirja osoitteessa https://fineli.fi/fineli/fi/ruokapaivakirja).

Merkitse yksi ruoka-aine tai ruokalaji yhdelle riville. Merkitse ruokien ja juomien tarkat nimet (esim. Vaasan ruispalat, Keiju 70 %, rasvaton maito, viili 1 %). Arvioi syömäsi määrät talousmittoina (tl, rkl, dl, lasi, iso muki, viipale, puolet 400 gramman eineslaatikosta), jos et tiedä tarkkaa grammamäärää.

Esimerkki

Aika ja paikka	Syöty ruoka tai juoma	Määrä
12.6. klo 7.00, kotona	Tee	iso mukillinen
	sokeri	1 pala
	Ruispalat	2 viipaletta
	Flora 60 %	2 tl
	Arla edam 24 %	2 siivua
	karpalo, tuore	kourallinen
12.6. klo 12, kotona	makaronilaatikko	Iso annos, 250 grammaa
	Salaatti	Pieni lautanen, 150 g
	ruispalat	2 viipaletta
	Flora 60 %	2 tl
	Arla edam 24 %	2 siivua
12.6. klo 12, työpaikka	broilerikastike	Iso annos, 250 grammaa
	Riisi, keitetty	Keskikokoinen annos, 150 g
	Salaatti	Pieni lautanen, 150 g
	ruispalat	2 viipaletta
	Flora 60 %	2 tl
	Arla edam 24 %	2 siivua

[DOWNLOAD THE FILE: CLICK FROM THREE DOTS ON THE UPPER RIGHT CORNER OF THE WINDOW -> "LATAA/DOWNLOAD"]

FOOD DIARY

Record the food diary for three days (not necessarily consecutive days). Record all consumed foods and drinks as accurately as possible. Be honest, and don't change your habits due to the food diary. If possible, record also all nutritional supplements used.

Food diary is submitted via questionnaire link:
(https://form.jotformeu.com/71572116273352). You can fill the food diary in the format specified in this document (pages 1-3), or using other formats (e.g. using the free food diary database provided by Finnish National Institute for Health and Welfare, "THL": https://fineli.fi/fineli/en/ruokapaivakirja?)

Record one foodstuff/dish on each row. Mark the exact names of the foods and drinks (e.g. Vaasan ruispalat, Keiju 70 %, cottage cheese 1 %). Estimate the amounts based on household measures (tbsp, tsp, dl, glass, slice) in case you are not aware of the exact amount in grams.

Example

Time and place	Food or drink	Amount
12.6. at 7.00, home	Tea	Big mug
	Ruispalat	2 slices
	Flora 60 %	2 tsp
	Arla edam 24 %	2 slices
	strawberry, tuore	Handful
12.6.. at 12, home	Macaroni and cheese	Big portion, 250 grams
	Salad	Small plate, 150 g
	Ruispalat	2 slices
	Flora 60 %	2 tsp
	Arla edam 24 %	2 slices
12.6. at 12, work place	Chicken sauce	Big portion, 250 grams
	Rice, boiled	Average portion, 150 g
	Salad	Small plate, 150 g
	Ruispalat	2 slices
	Flora 60 %	2 tsp
	Arla edam 24 %	2 slices

Appendix 4. Questionnaire in Finnish and in English.

0% 0 / 37 Fields Completed.

Finnish

CROSSFIT JA RAVITSEMUS SUOMESSA

Vaihda kyselyn kieli sivun yläoikealta / Change questionnaire language on the right top corner of the page

----

Teen gradua CrossFit-urheilijoiden ravitsemuksesta, ja haluaisin että osallistut tutkimukseeni (onnistuu etänä). Tutkimukseen osallistuaksesi sinun tulee pitää ruokapäiväkirjaa 3 päivän ajan, ja tämän lisäksi täyttää tietoja kyseisten päivien harjoituksista tämän web-kyselylomakkeen kautta.

Tarkka ohjeistus ruokapäiväkirjan täyttämiselle löytyy viestin lopusta. Kiitokseksi tutkimukseen osallistumisesta saat halutessasi kirjallista palautetta ruokavaliostasi. Halukkaille toimitan tutkimukseni sen valmistuttua.

Voit osallistua kyselyyn, jos olet yli 18-vuotias ja vastaat kyllä kohtiin 1 ja/tai 2:

1. Olet kisannut viimeisen kahden vuoden aikana (2015–2017) jossain seuraavista suomalaisista CrossFit-kisoista rx-tasolla: Karjalan Kovin, Unbroken, Winter War; ja/tai

2. Olet sijoittunut vuoden 2016 ja/tai 2017 CrossFit Openissa 100 parhaan joukkoon Suomessa omassa ikäryhmässäni (rx individual men tai rx individual women)

OSALLISTUMINEN:

1. TÄYTÄ RUOKAPÄIVÄKIRJAA 3 PÄIVÄN AJAN

- Varaa aikaa noin 15–20 minuuttia per päivä.
- Päivien ei tarvitse välttämättä olla peräkkäisiä.
- Ohje ruokapäiväkirjan täyttöön täältä

2. LÄHETÄ VALMIS RUOKAPÄIVÄKIRJA JA VASTAA TÄHÄN LYHYEEN WEB-KYSELYYN

- Ruokapäiväkirja lähetetään tämän web-lomakkeen kautta
- Vastaathan mahdollisimman pian, kuitenkin **30.6.2017 mennessä**

Treeniterveisin

Johanna Ihatsu

Graduntekijä, Liikuntalääketiede

Itä-Suomen yliopisto

ihatsu.johanna@gmail.com

+358 50 400 4982

Aloita kysely

Taustatietosi

Nimi *

Etunimi

Sukunimi

Syntymävuosi *

Sukupuoli *

- Nainen
- Mies

Pituus (cm) *

Paino (kg) *

Takaisin Seuraava

CrossFit

CrossFit-box, jossa jäsenenä

Missä muussa paikassa treenaat CrossFitiä?

Kuinka monta tuntia viikossa treenaat CrossFitiä keskimäärin? *

Kuinka monta vuotta olet harrastanut CrossFitiä? *

Mahdollinen päälaji(t) ennen CrossFitin aloittamista

Harrastatko tällä hetkellä jotain muuta lajia kuin CrossFit? *

- Kyllä
- En

Kerro, mitä muuta lajia harrastat CrossFitin lisäksi *

Missä seuraavista kilpailuista olet kisannut ja/tai sijoittunut kyseiselle sijalle? Valitse kaikki sopivat *

- [ ] Karjalan Kovin 2016
- [ ] Karjalan Kovin 2015
- [ ] Unbroken 2017
- [ ] Unbroken 2016
- [ ] Unbroken 2015
- [ ] Winter War 2017
- [ ] Winter War 2016
- [ ] Winter War 2015
- [ ] CrossFit Open top 100 in Finland (rx individual men/rx individual women) 2017
- [ ] CrossFit Open top 100 in Finland (rx individual men/rx individual women) 2016
- [ ] Joku muu

Takaisin Seuraava

Harjoituspäiväkirja

Päivä 1

Päiväys *

Päivä . Kuukausi . Vuosi

Päivän harjoituksen/harjoituksien pituus (h) *

ex: 23

Harjoituksen intensiteetti *

Harjoituksen intensiteetti "Joku muu", mikä? *

Harjoituksen sisältö *

Päivä 2

Päiväys *

Päivä . Kuukausi . Vuosi

Päivän harjoituksen/harjoituksien pituus (h) *

ex: 23

Harjoituksen intensiteetti *

Harjoituksen intensiteetti "Joku muu", mikä? *

Harjoituksen sisältö *

Päivä 3

Päiväys *

Päivä . Kuukausi . Vuosi

Päivän harjoituksen/harjoituksien pituus (h) *

ex: 23

Harjoituksen intensiteetti *

Harjoituksen intensiteetti "Joku muu", mikä? *

Harjoituksen sisältö *

Takaisin Seuraava

Ruokapäiväkirjan alkukartoitus

Ruokavaliosi erityispiirteet *

- [ ] Gluteeniton ruokavalio
- [ ] Laihdutusruokavalio
- [ ] Kasvisruokavalio
- [ ] Zone-ruokavalio
- [ ] Paleo-ruokavalio
- [ ] Ruoka-aineallergia
- [ ] Diabeetikon ruokavalio
- [ ] En noudata mitään erityisruokavaliota
- [ ] Muu

Ruoka-aineallergiasi

Vältätkö vapaa-ehtoisesti jotain tiettyä ruoka-ainetta? *

- Kyllä
- En

Mitä ruoka-ainetta vältät ruokavaliossasi? *

Liitä ruokapäiväkirjasi *

Lataa tiedosto(t)

Ruokapäiväkirja täytetään 3 päivän ajalta. Päivien ei tarvitse välttämättä olla peräkkäisiä päiviä

Takaisin | Seuraava

Kyllä kiitos, haluan vastaanottaa analyysin ruokapäiväkirjastani s-postiini *

- Kyllä
- En

Kyllä kiitos, haluan vastaanottaa tutkimuksen sen valmistuttua *

- Kyllä
- En

S-postisoitteesi *

Vapaa kenttä kysymyksille, lisätiedoille ja kommenteille

Mobile Responsive Widget

Your form will be automatically adjusted to fit a mobile screen.

Progress Bar Widget

The progress bar will appear at the top of your form.

Lähetä vastauksesi

Takaisin

English (UK)

CROSSFIT JA RAVITSEMUS SUOMESSA

Vaihda kyselyn kieli sivun yläoikealta / Change questionnaire language on the right top corner of the page

----

This Master's thesis about nutrition of the Finnish CrossFit athletes, and would like you to participate (done remotely). To participate, you must record food diary for 3 days and fill information about your training on those days.

Specified instructions for the food diary and link to the questionnaire can be found at the end of this page. If you want, you will receive a personal analysis on your nutrition and also the finished research afterwards.

You are invited to take part in this questionnaire if you are 18-years-old or older and you answer "yes" to point(s) 1 and/or 2:

1. You have qualified for at least one of the following Finnish CrossFit competitions between 2015–2017 on rx-level: Karjalan Kovin, Unbroken, Winter War; and/or

2. You positioned yourself to the Finland top 100 in the CrossFit Open in 2016 and/or 2017 in your own age group (rx individual men or rx individual women)

PARTICIPATION:

1. RECORD FOOD DIARY FOR 3 DAYS

- Filling the food diary takes around 15-20 minutes per day.
- Days do not have to be consecutive.
- Instructions for the food diary here

2. SUBMIT THE FINISHED FOOD DIARY AND ANSWER THIS WEB-QUESTIONNAIRE

- Finished food diary is submitted via this web-questionnaire
- Please submit your answers as soon as possible, **deadline is Friday 30th of June 2017.**

Best regards,

Johanna Ihatsu

Master's thesis worker, Exercise Medicine

University of Eastern Finland

ihatsu.johanna@gmail.com

+358 50 400 4982

Start questionnaire

0% 0 / 37 Fields Completed.

Demographic information

Name *

First Name | Last Name

Year of birth *

Sex *

Female

Male

Length (cm) *

Weight (kg) *

Back | Next

13% 5 / 37 Fields Completed.

CrossFit

Membership in CrossFit-box

How many hours per week do you train CrossFit on average? *

For how many years have you trained CrossFit? *

Possible previous sports done before starting CrossFit

Do you do also other sports than CrossFit at the moment? *

- Yes
- No

In which of the following competitions have you participated or gained position as an athlete (choose all applicable)? *

- Karjalan Kovin 2016
- Karjalan Kovin 2015
- Unbroken 2017
- Unbroken 2016
- Unbroken 2015
- Winter War 2017
- Winter War 2016
- Winter War 2015
- CrossFit Open top 100 in Finland (rx individual men/rx individual women) 2017
- CrossFit Open top 100 in Finland (rx individual men/rx individual women) 2016
- Other

Back Next

Training records

Day 1

Date *

Day . Month . Year

Length of the training session(s) (h) * ex: 23

Intensity of the training session(s) *

Specify the contents of the training session(s) *

Day 2

Date *

Day . Month . Year

Length of the training session(s) (h) * ex: 23

Intensity of the training session(s) *

Specify the contents of the training session(s) *

Day 3

Date *

Day - Month - Year

Length of the training session(s) (h) *

ex: 23

Intensity of the training session(s) *

Specify the contents of the training session(s) *

Back Next

63% 21 / 33 Fields Completed.

Information regarding the food diary

Your diet's characteristics *

- Gluten-free
- Weight loss
- Vegetarian/vegan
- Zone
- Paleo
- Food allergy
- Diabetic
- No specific diets
- Other

Do you voluntarily avoid any foodstuffs? *

- Yes
- No

Attach your food diary *

Download file(s)

The three-day food diary does not have to include consecutive days.

Back Next

77% 24 / 31 Fields Completed.

Yes, I will gladly receive nutrition analysis to my email based on my food diary *

- Yes
- No

Yes please, send me the research when it is finished *

- Yes
- No

Questions, additional information and comments

Submit answers

Back

Appendix 5. Cover letter for questionnaire.

MASTER’S THESIS: DIETARY HABITS OF FINNISH CROSSFIT ATHLETES

(for English version, see below)

Arvon CrossFittaaja,

Teen gradua CrossFit-urheilijoiden ravitsemuksesta, ja haluaisin että osallistut tutkimukseeni (onnistuu etänä). Tutkimukseen osallistuaksesi sinun tulee pitää ruokapäiväkirjaa 3 päivän ajan, ja tämän lisäksi täyttää tietoja kyseisten päivien harjoituksista. Tarkka ohjeistus ruokapäiväkirjan täyttämiselle ja linkki kyselyyn löytyvät viestin lopusta.

Kiitokseksi tutkimukseen osallistumisesta saat halutessasi kirjallista palautetta ruokavaliostasi. Halukkaille toimitan tutkimukseni sen valmistuttua.

Voit osallistua kyselyyn, jos olet yli 18-vuotias ja vastaat "kyllä" kohtiin 1 ja/tai 2:

1. Olet kisannut viimeisen kahden vuoden aikana (2015–2017) jossain seuraavista suomalaisista CrossFit-kisoista rx-tasolla: Karjalan Kovin, Unbroken, Winter War; ja/tai
2. Olet sijoittunut vuoden 2016 ja/tai 2017 CrossFit Openissa 100 parhaan joukkoon Suomessa omassa ikäryhmässäsi (rx individual men tai rx individual women)

OSALLISTUMINEN:

1. TÄYTÄ RUOKAPÄIVÄKIRJAA 3 PÄIVÄN AJAN

- Varaa aikaa noin 15–20 minuuttia per päivä.
- Päivien ei tarvitse välttämättä olla peräkkäisiä.
- Ohje ruokapäiväkirjan täyttöön:

https://www.dropbox.com/s/s50piejbs6h7e54/FI_Ruokap%C3%A4iv%C3%A4kirja%20ohjeineen.doc?dl=0

2. LÄHETÄ VALMIS RUOKAPÄIVÄKIRJA JA VASTAA LYHYEEN KYSELYYN

- Kyselyyn pääset tästä: https://form.jotformeu.com/71572116273352
- Vastaathan mahdollisimman pian, kuitenkin 30.6.2017 mennessä

Lisätietoa aiheesta: Vastaavaa tutkimusta ei ole aikaisemmin tehty Suomessa. Vastauksesi on tärkeä, jotta saamme paremman käsityksen siitä, millainen CrossFit-urheilijoiden ravitsemus on, ja miten ne vastaavat lajin vaatimuksia. Kyselyyn osallistuminen on vapaaehtoista. Kenenkään yksittäistä vastausta ei voi lopullisesta tutkimuksesta erottaa, ja siten vastaajaa ei voi tunnistaa. Vastaukset käsitellään ehdottoman luottamuksellisesti, ja vastausten tulokset julkaistaan ainoastaan yhteenvetomuodossa.

Kiitos paljon jo etukäteen vastauksistasi! Jos tulee kysyttävää, otathan minuun yhteyttä.
Treeniterveisin

Johanna Ihatsu
Graduntekijä, Liikuntalääketiede
Itä-Suomen yliopisto
ihatsu.johanna@gmail.com
+358 50 400 4982

IN ENGLISH:

Dear CrossFitter,

I am conducting a Master's thesis about nutrition of the Finnish CrossFit athletes, and would like you to participate (done remotely). To participate, you must record food diary for 3 days and fill information about your training on those days. Specified instructions for the food diary and link to the questionnaire can be found at the end of this message.

If you want, you will receive a personal analysis on your nutrition and the finished research afterwards.

You are invited to take part in this questionnaire if you are 18-years-old or older and you answer "yes" to point(s) 1 and/or 2:

1. You have qualified for at least one of the following Finnish CrossFit competitions between 2015–2017 on rx-level: Karjalan Kovin, Unbroken, Winter War; and/or
2. You positioned yourself to the Finland top 100 in the CrossFit Open in 2016 and/or 2017 in your own age group (rx individual men or rx individual women)

PARTICIPATION:

1. RECORD FOOD DIARY FOR 3 DAYS

- Filling the food diary takes around 15-20 minutes per day.
- Days do not have to be consecutive.
- Instructions for the food diary: https://www.dropbox.com/s/zixg30gzcu820mm/EN_Food_diary_template_and_instructions.doc?dl=0
- Finished food diary is submitted via questionnaire link (see step 2)

2. SUBMIT THE FINISHED FOOD DIARY AND ANSWER QUESTIONNAIRE

- Link to the questionnaire: https://form.jotformeu.com/71572116273352
- Please submit your answers as soon as possible, deadline is Friday 30th of June 2017.

More information: This research is the first in its field in Finland, and all answers are highly appreciated. Your answers help us to get understanding about nutritional factors correlating with success in CrossFit. The questionnaire is voluntary. Your answers are handled with absolute confidentiality and they will be published only as a summary together with all other answers.

Thank you so much for your time and answers! If you have any questions, please contact me.

Best regards,

Johanna Ihatsu
Master's thesis worker, Exercise Medicine
University of Eastern Finland
ihatsu.johanna@gmail.com
+358 50 400 4982