Gamification can influence food behavior in adolescent athletes

Master's thesis
Henna Vepsäläinen
Division of Nutrition
Department of Food and Environmental Sciences
University of Helsinki
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Author
Henna Reetta Vepsäläinen

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Abstract

Introduction: The nutrition knowledge of the adolescent athletes is usually of good quality, but they still have same problems in their diets as the majority of the population. The interventions aiming at improving the health of adolescents have mostly been conducted in school environment, and lectures, discussions, and enhanced physical activity sessions have been commonly used. Only a few studies using mobile devices have been conducted. The academic research concerning gamification, the use of game design elements in non-game context to motivate and engage users, is even more scarce.

Aims of the study: The main objective of the study was to find out if the eating habits of the adolescent athletes could be influenced using game-like smartphone application. The change in eating behavior obtained using the gamified approach was compared with that resulting from conventional dietary tutoring.

Materials and methods: Adolescent basketball and soccer players were recruited to the study. Of the 53 participants, 18 (34%) were basketball players and 35 (66%) soccer players. The participants were randomized to game (24, 45%) and tutorial (29, 55%) groups. The participants in the game group kept visual food journals during the four week study period using a smartphone application. The meals loaded to the application were given scores if specific food items defined in the rules were present and the participants competed with each other. The tutorial group members took part in a group meeting discussing a healthy diet. Food intake was measured at baseline, after the intervention, and four weeks post intervention using food frequency questionnaire (FFQ) specifically designed for the study. The changes occurring during the intervention were examined within groups. In addition, differences in the food consumption changes were compared between the game and tutorial groups.

Results: Altogether 40 participants (77%) completed the FFQ after the intervention. Baseline characteristics of the participants were similar in both groups. Basketball players were more active in the game group compared to the soccer players, but the activity decreased during the intervention among all the participants. No statistically significant changes in food behavior were detected among the female athletes in the game or in the tutorial groups. Among the male athletes in the game group, the consumption of milk with 1% or more fat decreased 2.16 times per day (SD 1.88, $p = 0.028$) and milk in total decreased 1.47 times per day (SD 1.82, $p = 0.028$). The male athletes in the tutorial group increased their consumption of vegetables, fruits, and berries 1.35 times per day (SD 1.89, $p = 0.024$) and nuts 1.50 times per week (SD 2.24, $p = 0.019$). The smartphone application was thought to be fun, challenging, and educational.

Discussion: The male athletes showed more changes in their diets during the intervention period compared to the female athletes. The diets of the female athletes were of good quality already at baseline. Among the male athletes, both the gamified and the more conventional interventions were effective. In the future, the two intervention methods could be combined to enhance the role of social support and to enable individual tailoring.

Keywords
Gamification, mHealth, adolescents, athletes, food behavior

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Additional information
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Tiedekunta	Laitos
Maatalous-metsätieteellinen tiedekunta	Elintarvike- ja ympäristötieteiden laitos

Tekijä
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Työn nimi
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Tiivistelmä

Johdanto: Nuorten urheilijoiden ravitsemustietämys on usein hyvää, mutta heidän ruokavaliossaan on silti samoja ongelmia kuin valtaväestöllä. Nuorten terveyden kohentamiseen tähtääviä interventioita on toteutettu suurimmaksi osaksi kouluissa, ja niissä käytetään usein luentoja, keskusteluja ja tehostettuja liikuntatuokioita. Toistaiseksi mobiililaitteita hyödyntäviä interventioita on toteutettu vain muutamia. Vielä harvemmassa on pelillistämistä (ei-pelillisten elementtien käyttö muussa kuin peliympäristössä motivoimaan ja sitouttamaan käyttäjiä) koskeva tieteellinen kirjallisuus.

Tavoitteet: Työn päätavoitteena oli tutkia, voidaanko nuorten urheilijoiden ruoankäyttöön vaikuttaa pelinomaisella älypuhelinsovelluksella. Vertailumenetelmänä käytettiin pienryhmäkeskustelua.

Aineisto ja menetelmät: Tutkimukseen rekrytoiduista 53 tutkittavasta 18 (34 %) oli koripalloilijoita ja 35 (66 %) jalkapalloilijoita. Tutkittavat satunnaistettiin peli- (24, 45 %) ja pienryhmiin (29, 55 %). Peliryhmään kuuluvat pitivät kuvallista ruokapäiväkirjaa älypuhelinsovelluksen avulla neljän viikon tutkimusjakson ajan. He saivat pisteitä sovellukseen lataamistaan aterioista, jos kuvissa näkyi tiettyjä säännöissä määriteltyjä elintarvikkeita. Peliryhmään kuuluvat kilpailivat pisteistä keskenään. Pienryhmään kuuluvat osallistuivat ryhmäkeskusteluun, jonka aiheena oli terveellinen ruokavalio. Ruoankäyttöä mitattiin tutkimuksen alussa, intervention päätyttyä sekä neljä viikkoa intervention jälkeen tutkimukseen kehitetyn ruoankäytön frekvenssilomakkeen (FFQ, engl. food frequency questionnaire) avulla. Intervention aikana tapahtuvia muutoksia tarkasteltiin ryhmien sisällä ja lisäksi vertailtiin ruoankäytössä tapahtuneiden muutosten eroja ryhmien välillä.

Tulokset: Kaikkiaan 40 tutkittavaa (77 %) täytti FFQ-lomakkeen intervention jälkeen. Ryhmien taustat eivät eronneet toisistaan. Koripalloilijat olivat jalkapalloilijoita aktiivisempia peliryhmässä, mutta aktiivisuus laski kaikkien peliryhmään kuuluvien keskuudessa intervention aikana. Naisurheilijoiden ruoankäytössä ei havaittu tilastollisesti merkittäviä muutoksia kummassakaan ryhmässä. Peliryhmään kuuluvat miesurheilijat vähensivät muun kuin rasvattoman maidon käyttöä 2,16 kertaa päivässä (SD 1,88; p = 0,028) ja maidon (rasvaton ja muut laadut yhteensä) käyttöä 1,47 kertaa päivässä (SD 1,82; p = 0,028). Pienryhmään kuuluvat miesurheilijat lisäsivät kasvisten, hedelmien ja marjojen käyttöä 1,35 kertaa päivässä (SD 1,89; p = 0,024) sekä pähkinöiden käyttöä 1,50 kertaa viikossa (SD 2,24; p = 0,019). Älypuhelinsovellusta pidettiin hauskana, haastavana ja opettavaisena.

Johtopäätökset: Miesurheilijoiden ruoankäytössä havaittiin enemmän muutoksia kuin naisurheilijoiden ruoankäytössä. Jo lähtötilanteessa naisurheilijoiden ruokavaliot olivat lähellä suosituksia. Sekä pelillistetty että perinteisempi interventio olivat tehokkaita ruokakäyttäytymisen muokkaajia miesurheilijoiden keskuudessa. Tulevaisuudessa nämä kaksi interventiomenetelmää voisi yhdistää, mikä lisäisi sosiaalisen tuen roolia ja mahdollistaisi henkilökohtaisen lähestymistavan.

Avainsanat
Pelillistäminen, mHealth, nuoret, urheilijat, ruokakäyttäytyminen

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Muita tietoja
Ohjaajat: Maijaliisa Erkkola ja Mikko Lehtovirta

Preface

When I first started my studies in the Department of Food and Environmental Sciences, I could not imagine that only two years later I would be writing my Master's thesis. Although I am a highly organized person, I like to think that the best things in life happen with minimal or non-existant planning, by chance. When I got the opportunity to work in the BerryUp project, I did not hesitate but attacked the job. And indeed, it proved to be a truly great project with ups and downs; a challenging yet inspirational task.

Working as a full member of a research team has been very educational. My supervisors Maikki and Mikko have, no doubt, been the best supervisors one could hope. I have also received support from other members of the team: Michael Quarshie, CEO at Wellness Foundry; Anna Aistrich, a health educator consultant for Wellness Foundry; and Mikael Fogelholm, Professor in Nutrition at University of Helsinki. In addition, Arto Ahonen from Wellness Foundry has offered me some indispensable technical support, whereas the statistical problems were solved with the help of Mikko Kosola.

This project would not have been finished without the mental support from all of my great fellow students. I am truly grateful to Saara, Ilona, Ansku, Martta, Moila, and Laura, just to mention a few of them, for encouraging me in my project and always being there as the most delightful lunch companion.

Last, but not least, I thank my family for their understanding and support through all the years I have spent studying. I promise not to start over any more. Special thanks go to my husband, who has suffered more than enough because of my occassionally manic study pace.

Henna Vepsäläinen
Mäkelänrinne, 3.12.2013

Contents

Abbreviations and definitions

BMD	Bone mineral density
BMI	Body mass index
CI	Confidence interval
DASS	Depression, anxiety, stress scale
ESA	Emotional self-awareness
FFQ	Food frequency questionnaire
GPS	Global positioning system
HBA	Helsinki basketball academy
HbA1c	Glycated (glycosylated) hemoglobin
HJK	Helsingin Jalkapalloklubi, Finnish soccer club
ICT	Information and communications technology
mHealth	Mobile health, the practice of medicine/public health supported by mobile devices
NHL	National Hockey League
OR	Odds ratio
PA	Physical activity
RR	Risk ratio
SD	Standard deviation
STD	Sexually transmitted diseases

1 Introduction

Children and adolescent need sufficient and diverse diet to maintain normal growth and development. Proper diet is also essential to the development of the cognitive skills (1). Furthermore, eating habits, as well as physical activity patterns, formed in childhood tend to persist into adulthood (2,3). Hence, it is important to take notice of the diets of the children and adolescents. During adolescence, the need for energy and nutrients are especially high because of growth and bone mineralization (4,5).

In Finland, the National Nutrition Council has given the nutrition recommendations for the whole population (6). These recommendations include references for nutrient intake for different age groups, but no separate nutrition recommendations for adolescents exist. However, nutrition recommendations for adults can be applied taking high nutritional demands of the adolescents into account. As part of the nutrition recommendations, the food plate model presented in Figure 1 is designed to give the consumers simple advice on how to build a recommended and nutritious meal, and the model is commonly in use in Finnish health education. The recommendations for the young athletes follow the same guidelines: they are advised to eat breakfast every morning, enjoy healthy snacks, and rely on foods rather than supplements to provide needed nutrients (4). In addition, they should be encouraged to drink fluids before, during, and after exercise as well as consume additional carbohydrates during prolonged exercise.

Figure 1. The food plate model (7): half of the plate is filled with colorful vegetables, one forth with potatoes, rice, or pasta, and the last forth with meat or fish. In addition, one should enjoy whole-grain cereal product, such as rye bread with vegetable oil spread, low-fat milk or sour milk, and berries.

According to the results of Child Health Monitoring Development project (LATE-project) (8) only 34% of eight-graders (14–15 years) ate fresh vegetables every day at school. In addition, only 39% of the vocational school students and 43% of the upper secondary school students eat all the parts of the meal (9). The eating habits of young athletes have not been systematically studied in Finland, but a report published in the year 2001 suggested that more attention should be given to everyday diet of the young competing athletes instead of focusing on the diet of the competition days (10). According to the report, the diet of the athletes could be improved by increasing intake of energy, carbohydrates, and fiber and taking notice of the quality of the fats. In a more recent Belgian cross-sectional study (11) researchers found that less than one third of young athletes ate at least 250 g of fruits daily, and the use of vegetables was low. Still, the young athletes tend to have better nutritional knowledge than their non-athlete peers (12).

Young athletes usually get nutritional information from coaches, as well as from group classes, brochures, handouts, and individual counseling (13). Although the nutritional knowledge of young athletes may be of good quality (14), common misconceptions exist. For example, the use of amino acid, vitamin, mineral, and other supplements is widespread (13,15) although it is known that the use of supplements does not patch up the defects in the diet.

Affecting the eating habits of adolescents is challenging as the effects of proper diet are not necessarily immediately visible for them. Individual preferences (food preferences, hunger, meal patterns etc.), social (demographic characteristics, peers etc.), and physical environment (schools, vending machines etc.), as well as macrosystem factors (food advertising, beauty ideals etc.) all influence eating habits and food preferences with variable degrees (5,16). To positively influence adolescent eating behaviors dietetics and health professionals must, therefore, reach teenagers on all these levels.

One of the modern ways to engage adolescents is the use of technology, especially Internet and smartphones. The amount of the Finnish adolescents aged 16–24 with access to smartphones increased from 53% in the year 2011 (17) to 64% (18) in the course of one year, and in the future, smartphones will probably be even more prevalent. Technology-based and peer-modeling strategies as a tool to affect the eating habits of adolescents have indeed been proved to be promising (19). There is, however, only limited evidence concerning the effectiveness of the technology in health promotion among adolescents. In this thesis, a smartphone application is used in an intervention aimed at improving the nutritional quality of the diets of adolescent athletes.

2 Health promotion among adolescents

2.1 Why is health promotion needed?

Affecting the eating habits of adolescents is demanding. While teenagers acquire a more advanced range of cognitive skills and begin to be able to think of abstract scenarios and consider the possibilities and intangible consequences of their actions, they still have the desire to be accepted by peers (5). Food choices and eating behaviors are not only influenced by personal factors but also by those including parents and family, socioeconomic status, and sociocultural expectations. Furthermore, a limited knowledge and understanding of the importance and influence of nutrition on training and competing does not seem to lessen the influence that coaches, teammates, and parents have on the athlete (20).

In Finland, the National Nutrition Council has given recommendations for school meals in order to secure the nutrition of children and adolescents. The recommendations state that the school lunch should meet one third of the adolescents' daily energy and nutrient requirements, which is around 3.6 MJ or 860 kcal (21). There are, however, significant variations in energy requirements between individuals depending on the size of their body and the level of their physical activity: an active girl aged 17 years can require up to 12.7 MJ a day, in which case a regular school lunch of 3.6 MJ does not meet her requirements, which is more than 4 MJ (22). Although school meals in Finland are under regulation and generally fulfill the quality requirements, adolescents do not always find them attractive and might fail to eat all the parts of the school lunch (23). For example vegetables, fiber-rich bread, vegetable fat spread or vegetable oil dressing, and skimmed dairy products seem to be chosen less often than what is recommended.

There is only limited knowledge concerning eating behaviors and food choices of the Finnish adolescents. A study conducted among Finnish adolescents (23) showed that only 69% of boys and 68% of girls ate lunch at school every day. Boys tended to skip vegetables (only 60% of them ate the salad offered), whereas girls most often skipped dairy products (only 49% of them drank milk or sour milk).

Even fewer studies have investigated the quality of the diets of the Finnish athletes. It is, however, known, that they tend to have similar problems as the majority of the population: the quality of the fats should be improved and the intake of fiber, vitamins, and minerals increased (10). In a master's thesis examining the quality of ice hockey players' diet (24), it was found that 14% of ice hockey

players aged 16–20 years ate vegetables, fruits, and berries (fresh and cooked) less than once a day. Most players consumed fish once a week and enjoyed 2–3 slices of rye bread a day.

During the aforementioned study, the young ice hockey players received three lectures concerning nutrition (24). This is probably the most used form of nutritional counseling. It is applied in most of the sports clubs offering nutritional counseling and leads to knowledge-based approaches in targeting eating behaviors. Still, it is equivocal, if the nutrition knowledge of the athletes affects their dietary intake (25). Nutritional counseling is, among physical and psychological training services, offered to Finnish top athletes via Finnish Olympic Committee (26), but amateur athletes are often left without professional counseling. Since rest and nutrition play a key role in the development of adolescent athletes, increasing training volumes in adolescence can lead to increasing risk of injury (27). In addition, it seems that the prevalence of eating disorders is higher among athletes than among controls, and eating disorders are more common among athletes competing in leanness- and weight-dependent sports than those competing in other sports (28). To prevent young, promising athletes from injuring themselves and giving up their dream of becoming a professional athlete, it would be extremely important to affect the eating habits of adolescent athletes.

In conclusion, despite of scarce knowledge, it seems that increasing the use of wholegrain products, fish, vegetables, fruits, and berries would be beneficial for a majority of the population as well as for young athletes. Taking into consideration the increased energy, vitamin, and mineral requirements of the adolescent athletes, even more attention should be paid to their food choices. In addition, adolescence serves as a window of opportunity for nutritional interventions since healthy eating behaviors learned in childhood tend to remain. Nevertheless, the adolescents are a challenging target group for health interventions, and new ways for capturing their attention are needed.

In order to identify relevant health promotion intervention studies conducted among adolescents, Pubmed database was searched. The general search structure was (health promotion or synonyms) AND (adolescents or synonyms) AND (intervention or synonyms). The studies retrieved were browsed through and the most appropriate original papers were selected for further examination based on their abstracts. Only studies with healthy participants were considered. All in all, 15 studies were identified. Figure 2 describes the flow of papers. In this section, these studies are presented. Tables 1 and 2 summarize the studies conducted in school environments and outside schools, respectively.

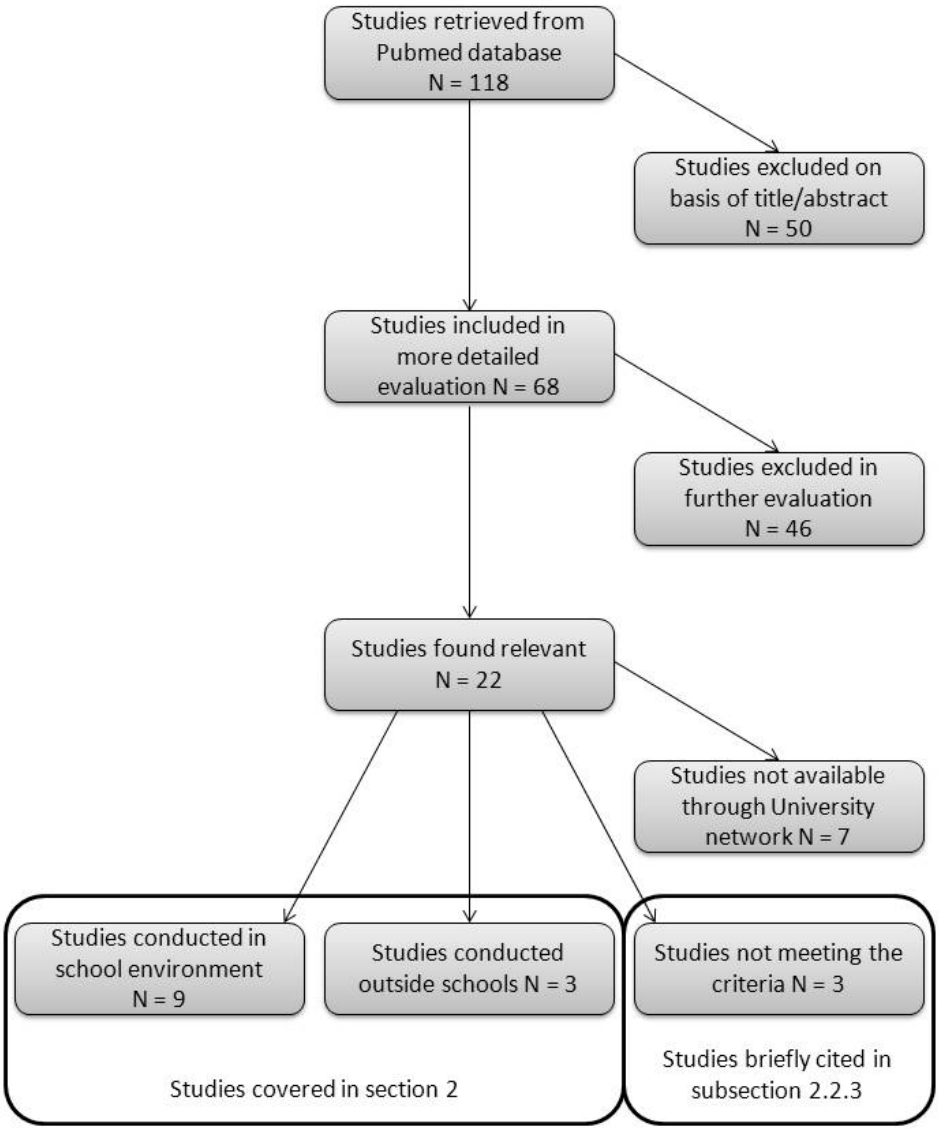

Figure 2. Flow of papers describing the retrieval of the original papers covered in this thesis. The most common reasons for excluding papers were outcomes not related to behavioral changes, overweight/obese or non-healthy participants in the studies, and age of the participants. In addition, six reviews or comments were excluded.

2.2 Traditional health promotion interventions

One of the most used theoretical frameworks in health promotion is Bandura's social cognitive theory. Social cognitive theory is a learning theory based on the idea that people do not learn new behaviors solely by trial and error but also by replicating the actions of others (29). For adolescent athletes social cognitive theory is especially applicable since teenagers are often under social pressure with regard to nutritional behavior. In health promotion, social cognitive theory distinguishes three basic processes of personal change: the adoption of new behavior patterns, their generalized

use, and their maintenance over time (30). In a successful health intervention, all of these aspects need to be taken into consideration.

Schools are a natural environment for health interventions: they reach the majority of the adolescents with diverse sociodemographic background and communicate with their parents. According to Bandura, a functioning intervention addresses values, normative beliefs, outcome expectations, and self-regulatory skills (30). Health promotion programs relying mainly on providing information or using rational orientation are relatively ineffective, whereas interventions with a social reinforcement orientation produce stronger effects (31). Interventions integrating school health programs with family and community efforts tend to be more successful compared to programs performed only at schools (32).

Multiple intervention studies aiming at improving the health of the adolescents or promoting healthy lifestyle have been performed in the 21st century (e.g. (33–35). The main outcomes are commonly measured by food frequency questionnaires (FFQ) or dietary recalls. There are, however, also interventions aiming at improving health education and the knowledge of the adolescents concerning nutrition, exercise, and healthy lifestyles in general. In this section, a summary of 12 intervention studies conducted among adolescents is presented.

2.2.1 Interventions implemented at schools

Most of the interventions aiming at improving the health of the adolescents have been conducted at schools. Since Bandura's social cognitive theory is often described to be the theoretical framework for the interventions, they usually consider the personal, environmental, and/or behavioral characteristics. Most of the studies have managed to trigger changes in the health behavior of the adolescents, but in general, it is hard to say which components of the interventions are the most effective ones. In this subsection, nine intervention studies are summarized. A round-up of the interventions, their primary outcomes, and results is resulted in Table 1. The interventions using mobile technology are discussed in section 2.2.

Of the nine studies examined, one was carried out with children under ten years of age (36) and one with young adults aged 18–24 (37). In the remaining seven studies, the participants were 11–18 years old. In two studies (37,38), the intervention was built into a school course and lasted 9–15 weeks, and in one study (34) the intervention was put into practice outside the curriculum although the school facilities were used. Four out of nine studies (33,35,36,39) can be described as continuous: the actual intervention had a duration of at least one school year.

Interventions

Although all of the nine studies were conducted at school environment, not all of them used actual environmental components. For example, Prochaska et al. (40) used interactive communication technology to screen disordered eating, physical activity, and dietary behaviors as well as to create an action or relapse-prevention plan to change health-related behaviors (41). They did not, however, offer health education nor did they change the school environment to support changes.

In four studies, changes in the school environment were reported (33,36,39,42). Nader et al. (36) engaged teachers and school food service providers as well as the parents. The participants received take-home packets of learning materials and activities and participated in events consisting of prizes, games, and activities. Mihas et al. (42) had posters and displays in the classroom to reinforce messages. In a Belgian school intervention (39), water and fruits were made available for the children, whereas food items not regarded as healthy (high-fat and sugar snacks, sugar-sweetened beverages) were not as readily available as before. In a Finnish study (33), healthy snacks were made available and fresh bread was offered at school lunch more often than before.

Most of the studies had lectures as part of the intervention. The lectures were usually given by teachers (33,35–38,42) and they dealt with dietary issues, attitudes, healthy behaviors, and physical activity. In some of the interventions (33,37,39,40,42), feedback concerning screening results, dietary intake, or physical activity was given to the participants or their parents. Parents were engaged in the interventions through meetings and newsletters. Drama workshops, discussions, video tape watching, interactive exercises, games, workbooks, enhanced sport or physical activity sessions, and/or text messages were used together with lectures in four studies (33–35,37,38). In a study with slightly elder participants (37), a "Happy Body Log" was kept to write down good things the participants did to their body daily.

Control groups

The use of control groups varied in the studies examined. One study (37) had no control group at all and used college students as participants, which may have led to the study population not being representative of the young adults in general. Four studies (33,35,38,42) had control group with no intervention at all. Two studies (36,39) had two groups with almost similar intervention procedures the only difference being the parental component added in top of the school-based intervention to examine the role of parents in health behavior change. One study (40) had three groups: two intervention groups (physical activity alone or in combination with dietary advice) and a control group

with no treatment. Jemmott et al. (34) used a design with two similarly structured intervention groups with separate goals (health promotion vs. sexually transmitted diseases (STD) risk reduction).

Effects on physical activity

A few studies have demonstrated the effectiveness of health interventions in improving physical activity (PA) of adolescents. Prochaska and Sallis (40) found that their interventions (physical activity and nutrition and physical activity alone) were efficacious in supporting boys' health behavior: physical activity increased in the intervention groups and decreased in the control group. However, for girls, mean physical activity decreased in all groups. Nevertheless, Covelli (38) demonstrated that an educational intervention can affect the amount of exercise in African American adolescents: a statistically significant difference between intervention and control groups was detected. In this rather small sample with few females the greatest difference was actually noted in the female groups. In addition, Jemmott et al. (34) found that participants in the health promotion intervention were significantly more likely to have met the physical activity guideline compared to the participants in STD risk reduction intervention in the past seven days (OR = 1.56, 95% confidence interval 1.29–1.89) over the 3-, 6-, and 12-month follow-ups despite the rather short intervention period (six days). In an Australian study (35), self-reported screen time decreased in the intervention group compared to the control group, but no differences in muscular fitness tests or accelerometer counts were detected.

Effects on food intake

In terms of fruit and vegetable intake, results from intervention studies are diverse. Prochaska and Sallis (40) did not detect statistically significant effects on fruit and vegetable consumption in their 3-month intervention study. In a study conducted in Finnish secondary schools (33), vegetable intake remained the same among girls in the intervention group as well as in the control group, whereas daily consumption of vegetables decreased among boys. Fruit intake remained nearly constant among intervention group but decreased among boys in the control group, but this difference was not statistically significant. However, reassuring results also exist: Covelli's intervention (38) resulted in increased daily intake of fruit and vegetables. When it comes to long-term effects, increased fruit intake could be seen in a Greek study (42) 15 days and one year after the intervention, although vegetable intake was unaltered. In addition, a greater percentage of health-promotion intervention participants met the guidelines for fruit and vegetable intake in South Africa compared to the STD risk reduction intervention participants (34).

Four studies have investigated the effects of the interventions on the consumption of different food items. Among 12–13 years old Greek pupils, educational intervention had both short- and long-term effects on red meat and poultry consumption: the changes were visible both 15 days and one year after the intervention (42). No effect on fish intake was detected. American college students decreased their consumption of soft drinks during a 15-week intervention (37). Changes in milk consumption were also detected. A school intervention in Finland (33) resulted in the increase of the frequency of consumption of rye bread among girls. In addition, the frequency of consumption of sweets decreased among girls. However, Lubans et al. (35) found no statistically significant differences in body mass index (BMI), body fat percentage, muscular fitness, or energy intake, although changes in body composition were all in favor of the intervention group.

Parental support

Although at least four of the studies examined used parental support as a part of the intervention, only two studies focused on exploring the effects of the parental component. Nader et al. (36) measured adult participation by the number of activity packets that an adult household member completed with the child. They found that positive activity and reinforcement of food choice by parents increased as the extent of the adult participation increased. Van Lippevelde et al. (39) assessed home-related determinants (home availability, parental encouragement, and parental support) by asking students to rate the items on a five-point scale. They detected an increase in fat intake from snacks in the intervention group whereas in the intervention with parental component group fat intake from snacks remained rather constant. In addition, almost 5% of the effect of the parental intervention component was mediated by changes in perceived parental support.

Adolescents' attitudes towards the interventions

In general, the adolescents tend to like the interventions aimed at improving their health. For example, 82% of the participants recommended PACE+ to others and 70% of the intervention participants intended to follow their PACE+ plans (40). Covelli, too, reported that the adolescents were interested in their health: after completion of the intervention, the participants continued to bring in friends for blood pressure measurements and to ask questions related to their diets (38). However, the interventions would probably benefit from more thorough involvement of the participants in the planning and implementation, as well as attractive data collection methods such as the Internet (33). Gender differences regarding the acceptability of interventions might exist: for example Jemmott et al. reported that a higher percentage of eligible girls (97%) than boys (92%) participated in their study (34).

Table 1. Summary of the school-based interventions among adolescents aiming at improving their health or promoting healthy lifestyle

Reference country Age of the participants, y Trial length N (% females)	Intervention group	Control group	Primary outcomes	Results
USA, 1996 (36) 8–9 3 years N/A (N/A)	School-based intervention with a family component: learning materials to be completed jointly by the child and a parent or adult figure in the home, events organized for families	School-based intervention: classroom curricula, school food service intervention, physical education	Health behavior questionnaire, dietary recall, PA checklist	Positive support for PA and reinforcement of food choice by parents increased as the extent of the adult participation increased
USA, 2004 (40) 11–14 3 months 138 (65%)	Two intervention groups: computer-supported intervention to promote adoption and maintenance of PA alone or in combination with fruit and vegetable consumption	No treatment	PA (measured with accelerometer), fruit and vegetable consumption (3-day food record)	PA increased among the boys in the intervention groups and decreased among the boys in the control group, no statistically significant effects on fruit and vegetable consumption
USA, 2006 (38) 14–17 9 weeks 48 (33%)	Two 90-minute classes per week (one day of lecture and discussion and one day focusing on exercise each week)	An American Heart Association pamphlet on hypertension in teenagers distributed to the control group participants at the end of the study	Health knowledge test, exercise questionnaire, 2-day dietary recall, blood pressure	Significant differences in knowledge, daily intake of fruit and vegetables, and exercise between the groups
Greece, 2009 (42) 12–13 1 year 199 (51%)	Educational intervention delivered by teachers during 12 weeks, parental component included	No health education intervention, no parental educational sessions	Dietary habits (measured with FFQ)	Fruit intake increased in the intervention group compared to the control group (seen 15 days after the intervention as well as one year after the intervention), no effect on vegetable or fish intake
USA, 2009 (37) 18–24 15 weeks 80 (88%)	Class lectures focusing on importance of nutrition related to prevention of chronic diseases and promoting active lifestyle (three times per week for 50 minutes per session)	No control group	Consumption of soft drinks and milk (measured with 3-day dietary record)	Consumption of soft drinks decreased, consumption of milk increased among the females, use of low fat milk decreased and fat free milk increased

Reference country Age of the participants, y Trial length N (% females)	Intervention group	Control group	Primary outcomes	Results
Finland, 2011 (33) 13–14 1 year 659 (N/A)	Development of healthy food environment, nutritional education implemented by teachers, parents' meetings, printed information	No treatment	Eating habits and frequency of food use (measured with FFQ, 48h dietary recall)	Among girls, the frequency of consumption of rye bread increased and that of sweets decreased in the intervention group compared to control group
South Africa, 2011 (34) 9–18 1 year 1057 (53%)	2-hour sessions including interactive exercises, games, brainstorming, role-playing and group discussions on six consecutive school days	Similarly structured intervention aimed at reducing STD risk	Fruit and vegetable consumption (measured with FFQ), self-reported PA, questionnaires measuring attitudes and intentions	A greater percentage of health promotion intervention participants than STD risk reduction intervention participants met the guidelines for fruit and vegetable intake and PA
Belgium, 2012 (39) 11–15 2 years 2840 (37%)	School-based intervention with parental component: informing the parents by means of a free CD and a leaflet and an interactive nutrition education meeting	School-based intervention: development of healthy food environment, personal feedback regarding fat intake, attitudes, and intentions	Fat intake (measured with self-administered questionnaire), home-related determinants (measured with questionnaire)	Fat intake from snacks did not increase in the parental intervention group unlike in the intervention group, almost 5% of the effect of the parental intervention component was mediated by changes in perceived parental support
Australia, 2012 (35) 12–14 1 year 357 (100%)	Enhanced sport sessions, seminars, nutrition workshops, lunch-time physical activity sessions, handbooks, accelerometers, parent newsletters, text messages	No treatment	BMI, fat percentage, several secondary outcomes (muscular fitness, dietary intake, screen time and self-perception)	No statistically significant differences in BMI, body fat percentages, muscular fitness, or energy intake, screen time decreased in the intervention group compared to the control group

2.2.2 Interventions conducted outside schools

A few interventions aiming at improving the health of adolescents have been carried out in environments other than schools. In this section, three intervention studies conducted in a primary care or general practitioner setting are presented (Table 2). Since health care systems vary all over the world, the results must be interpreted with care. Nevertheless, different study settings might introduce some useful information regarding adolescents' health interventions.

Interventions

One of the three studies (43) used human contact as a means of intervention: the participants met with a practice nurse to discuss their health and health related behavior for 20 minutes. No additional contact with research crew was offered, and the participants did not receive any written materials. Thus, this intervention was rather light. In the YOUTH study (44), the intervention consisted of group and individual meetings, phone calls, psychoeducational information, and a web-based study site offering peer support. Patrick et al. (45) used information technology in assessing the participants' nutrition target behaviors, physical activity target behaviors, and sedentary behaviors, as well as stage of readiness to make a behavior change. Thereafter, the computer guided the adolescent to develop behavior-change plans for one nutrition and one physical activity behavior. The plans were supplemented with a written guide consisting of information and worksheets, 11 telephone counselor calls, and a written parent manual.

Control groups

The use of control groups varied in the studies examined: one used a control group with the same objectives as the intervention group but with slightly lighter intervention components (44), the other had a sun protection intervention as a control group (45), and the third had a control group with no treatment whatsoever (43). All in all, the two studies conducted in the United States (44,45) had heavier intervention procedures as well as more accurate measurement methods. The British study (43) used only self-reported questionnaires apart from the saliva samples used to validate self-reported smoking.

Effects on physical activity

Like many of the intervention studies conducted in school environment, the three studies described here explored physical activity behaviors induced by the interventions. At three months, Walker et al. (43) detected no positive change in exercise in the intervention group compared to the control group (number of teenagers reporting positive change in the intervention and control groups were

18 (4%) and 12 (3%) respectively, p = 0.37). Still, significantly more teenagers in the intervention group reported some positive movement in stage of change for exercise compared to the teenagers in the control group (17% (86) of intervention group participants, 12% (54) of control group participants). In the PACE+ study (45), no significant difference in physical activity between groups was seen, but sedentary behaviors decreased in the intervention group compared to the control group among both sexes. Among the boys, active days per week increased in the intervention group compared to the control group. In the YOUTH study (44), an overall trend suggesting that physical activity declined in both study conditions was detected, but the study population had initially reported a rather high level of physical activity. Nevertheless, physical strength and fitness measures did not decline.

Effects on food intake

Changes in diet were reported in the two American studies (44,45). In the YOUTH study (44), girls in the intervention group increased their total calcium intake compared to the control group in both study years. In addition, their vitamin D intake increased compared to the control year in the first study year, and fruit and vegetable intake increased in both study years. Patrick et al. (45) found that girls in the intervention group were more likely to meet recommended health guidelines regarding saturated fat intake compared to the girls in the control group (RR = 1.33, 95 % CI 1.01–1.68). In addition, they studied the intervention dose by logistic regression and found that the intervention dose (measured with completed counselor calls) had an effect on saturated fat intake, fruit and vegetable intake, and screen time in girls receiving the intervention.

Representativeness of the studies

Interventions conducted at schools can reach a larger and more representative population, but on the other hand, the health care setting is a promising environment for such interventions since pediatric patients are influenced by physician advice and are receptive to health behavior recommendations, and in general, the public views physicians as credible source of health information (46). However, the intervention studies examined in this subsection reached a variable portion of their target populations (5–73%) indicating at least partial selection of the participants in the studies.

Table 2. Summary of healthy lifestyle promoting interventions among adolescents conducted in a primary care or general practitioner setting

Reference country Age of the participants, y Trial length N (% females)	Intervention group	Control group	Primary outcomes	Results
USA, 2006 (44) 14–16 2 years 82 (100%)	Meetings (group and individual), activities, coaching calls, information, goal setting, web site providing information and an individual point accumulation	Annual study visits, web site with no study-specific lifestyle targets or personalized feedback, team meetings	Bone mineral density (BMD), bone mineral content, body mass index, lean and fat masses, dietary intake (calcium, vitamin D, fruits and vegetables, soda), PA	The intervention group members increased their calcium, vitamin D, and fruit and vegetable intake compared to the control group members, BMD increased more in the intervention group in the spine and trochanter regions compared to the control group
USA, 2006 (45) 11–15 1 year 819 (53%)	Computer-assisted, tailored behavior change progress plan, telephone counselors (11 x 10–15 minutes)	Sun protection intervention with printed recommendations, two telephone calls	PA (measured with 7-day PA recall), dietary intake (measured with recall), screen time (self-reported)	Sedentary behaviors decreased in the intervention group compared to the control group, girls in the intervention group were more likely to meet guidelines regarding saturated fat intake, boys in the intervention group were more likely to meet guidelines regarding PA
Great Britain, 2002 (43) 14–16 1 year 1516 (51%)	A 20 minute consultation with a nurse to discuss health and health related behavior	No treatment	Mental and physical health, “stage of change” for health related behaviors (diet, exercise, smoking, drinking) (measured with self-administered questionnaires), use of health services	At three months significantly more adolescents in the intervention group indicated some positive movement in stage of change for diet and exercise

2.2.3 Other studies

Although most of the adolescents' health interventions are aimed at changing their behavior, one intervention with emphasis on children's health knowledge also exists (47). Shah et al. found that the health and nutrition-related knowledge improved in all children regardless of the type of school (government or private) after an educational intervention carried out over a period of six months. Their intervention consisted of lectures and several different activities (making posters, masks, cards, and cartoons, school plays, debates, cooking competitions etc.). No control group was used and the educative activities and questionnaire surveys were pursued during the non-academic periods in the school curriculum. Important as health education interventions are, they do not provide any information of the actual behavioral changes occurring in the life of adolescents.

In Sweden, an intervention project was carried out in an elementary school to find out if young students could be substantive participants in health promoting projects (48). In the end of the intervention, the students were encouraged to suggest proposals for what they wanted changed in the school in order to improve their health. From the students' proposals for change, six different categories were identified: social climate, influence on schoolwork, structure and orderliness, security, physical environment, and food for well-being. The researchers emphasized empowerment and participation as a tool for reducing inequalities in health consequent upon gender, class, and ethnicity. An American interview study (49) suggested promotion of home-based eating, improvement in the availability of healthy foods in school and neighborhood stores as well as targeted educational materials as tools for nutritional interventions. The latter is, in fact, often used in health interventions.

2.2.4 Summary

In conclusion, most of the adolescents' health interventions have taken place in school environment. Diverse results have been obtained: some interventions have managed to increase the physical activity or decrease the sedentary activities of the adolescents. Healthier eating habits, such as increased fruit and vegetable intake, have also been established among adolescents thanks to interventions.

While lectures, meetings, discussions, printed information, sport sessions, and parents' meetings are most commonly used, technology-based strategies have also been proved to be promising in health interventions (19). Information technology has already been used in a few intervention studies (35,39,44,45) but the possibilities emerged with the developing technologies, such as mobile devices and smartphones, have not been fully capitalized yet.

2.3 Mobile technologies as tools in health promotion (mHealth)

The practice of medicine and public health supported by mobile devices is termed mHealth (m-health or mobile health). During the last couple of years, opportunities for mobile technologies to play a pivotal role in health services have increasingly been recognized. Unfortunately, only few studies have demonstrated an impact on clinical outcomes (50) and most research evaluating mHealth interventions aiming at behavior change has taken place in developed countries (51). The use of mHealth in health education and promotion among adolescents has, to this day, been somewhat exiguous, although, for example in Finland, 64% of adolescents aged 16–24 have a smartphone in their own use and over 50% of them have used their smartphones to read magazines, play games, watch videos or photos, or interact in social media (18).

In order to identify mHealth studies conducted among adolescents, Pubmed database was searched. The general search structure was (mHealth or synonyms) AND (adolescents or synonyms). The studies retrieved were browsed through and the most appropriate original papers were selected for further examination. All in all, eight studies were identified, of which seven were available through University network. In addition, four study protocols using mHealth were found. Figure 3 describes the flow of papers. In this section, these studies and study protocols are presented. Table 3 summarizes the mHealth studies.

mHealth in the assessment of physical activity and eating habits

To date, only one study using electronic health technology for the assessment of physical activity and eating habits in adolescents exists. Schiel et al. (52) used a motion sensor integrated into a mobile phone with digital camera to assess time spent in exercise and energy intake among 124 adolescents (average age 13.5 years, SD 2.8). Energy intake was analyzed twice by separate researchers from photos of meals taken by the participants, and the mean calculated was taken as an objective estimate of the participants' energy intake, whereas subjective estimate was provided by the participants themselves. Researchers found that there were statistically significant differences in the objective and subjective measures of physical activity (for example, self-reported physical activity (min/day) 456.5, SD 231.3, physical activity assessed with motion sensor 290.4, SD 92.6). In addition, the participants tended to estimate their energy intake slightly lower compared to the objective energy intake.

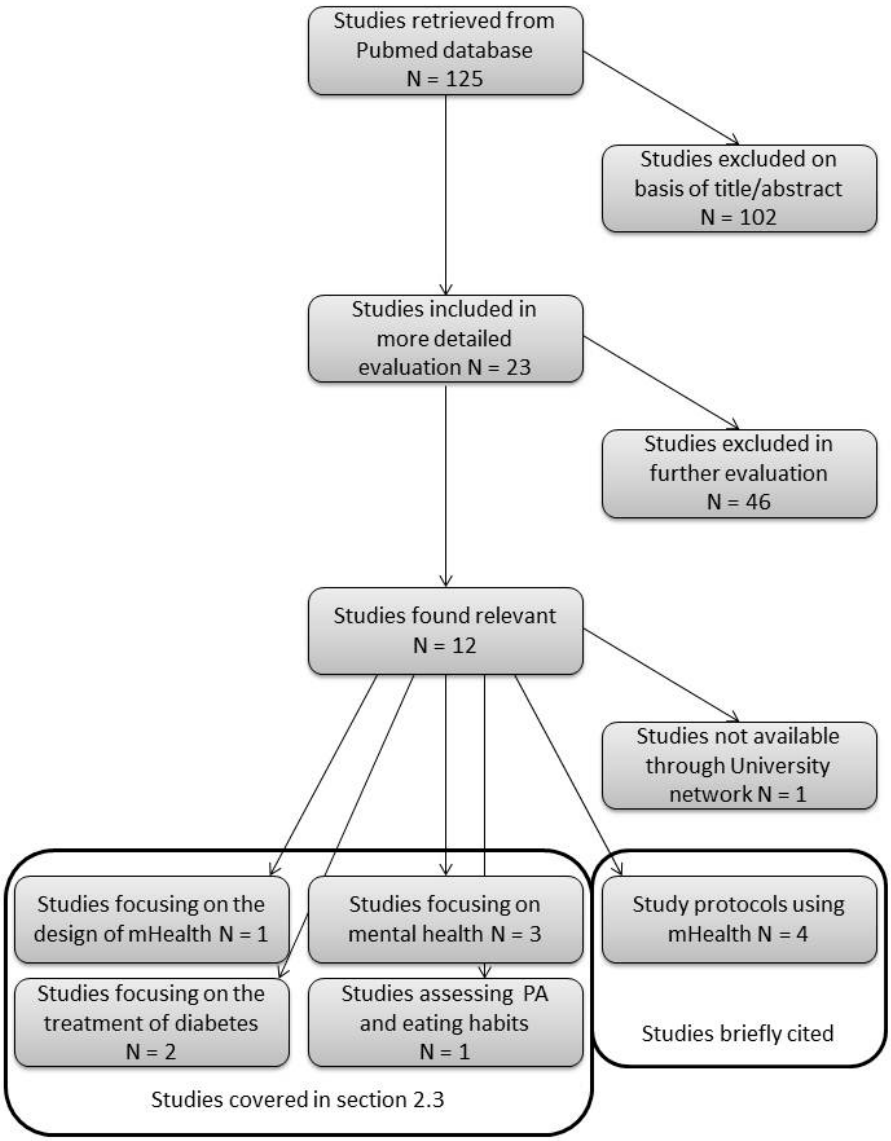

Figure 3. Flow of papers describing the retrieval of the original papers covered in this section. The most common reasons for excluding papers were outcomes not related to behavioral changes. In addition, six reviews were excluded.

mHealth in the treatment of type 1 diabetes

Two recent studies have focused on the treatment of type 1 diabetes in adolescents. Young diabetes patients are a reasonable target group for the development of mHealth solutions since they need to measure their blood sugar levels several times a day and they might benefit from a mobile solution which enables them to share the measured values with their parents or caregivers. In a clinical pilot (53) with 20 patients, daily average frequency of blood glucose measurement increased 50% from 2.4 readings per day to 3.6 readings per day. There was, however, no significant change in glycosylated hemoglobin (HbA1c, a form of hemoglobin used to monitor blood sugar control in patients with diabetes).

Frøisland et al. (54), too, observed that although metabolic control had improved in seven out of 12 patients at the end of their study, there were no statistically significant changes in HbA1c over the course of the intervention. These findings could be due to the small sample sizes, since there seems to be a correlation between the frequency of self-administered blood glucose measurements and HbA1c levels (55). Another reason for the unsatisfactory evidence offered by these mHealth studies is the lack of control group. Nevertheless, the adolescents seemed to be satisfied with applications: 14 (88%) participants would have continued using the system in the Canadian study (53), and ten out of 12 participants in the Norwegian study reported positive experiences with the two applications used (54).

mHealth in the assessment and management of mental health

So far, at least one mobile application has been developed for assessment and management of mental health. The *mobiletype* program (56) was carried out in Australian rural and metropolitan general practices. The intervention group monitored mood, stress, coping strategies, and daily activities as well as eating, sleeping, exercise patterns, and alcohol and cannabis use using a mobile phone application whereas the control group used an abbreviated *mobiletype* program assessing only current activities, sleep, exercise, and diet, that is to say, the modules pertaining mental health as per (mood, stress, alcohol and cannabis use) were removed. During the intervention, both groups showed a decrease in experienced depression, anxiety, and stress. Nevertheless, these findings were not primary and their statistical significance was not reported. Instead, a significant difference was found in observed emotional self-awareness (ESA) scores between groups six weeks after the intervention, with the intervention group mean ESA 6.6 points higher than the comparison.

In other measures of the *mobiletype* study (56), a significant group x time interaction effect signifying different ESA patterns over time between groups was found. In addition, there was a significant main effect for time for depression. In a secondary analysis (57), support was yielded for the hypothesis that self-monitoring increases ESA, which in turn decreases depressive symptoms for young people with mild or more depressive symptoms. However, the uneven distribution of participants to the study groups (intervention group 68, control group 46) as well as the self-monitoring conducted in both study groups may have harmed the reliability of the study.

The *mobiletype* application has also been used to study temporal mood changes associated with adolescent drinking (58). This study was not of interventional nature, but the mobile application was used to get information about the mood and mood changes before and after drinking episodes

in 14–17 years old adolescents. The study showed that in addition to being useful as a method of intervention, mobile devices can also be used as a tool for data collecting.

In addition to mobile applications, simple messages sent to participants' own mobile phones have been used in health interventions. Whittaker et al. (59) used a mixture of text messages, video messages of adolescents and celebrities, and animated cartoons in a trial aimed at preventing depression in adolescents. Both the intervention and the control group received two messages per day for nine weeks. Instead of focusing on mental health, the messages received by the control group members focused on healthy eating, sustainability of the environment, and cybersafety, and the participants were not aware of which program was the intervention. The primary results from this study are yet to be published. Nevertheless, the method seemed to be promising since 75% of the participants in the intervention group and 81% of the participants in the control group reported viewing at least half of the messages received. In addition, 67 % of the participants in the intervention group reported that the program helped them to be more positive whereas the respective percentage in the control group was 50%.

Designing mHealth applications

The development and design of mobile applications or mHealth programs is not simple, especially if the target group is adolescents. This in mind, researchers in several projects (53,54,59) have used the help of the adolescents in the development phase to achieve an attractive application with maximum usability. A formative study assessing adolescents' health information needs (60) states that the applications should be easily used, tailored for adolescents', and private as well as use simple language. A Canadian study (53) conducted recently described the design phase of an application developed to manage type 1 diabetes in adolescents, and they found that the patients require fast transactions, data collection and support for decision making, as well as the possibility to share diabetes-related information, including test results. In a Norwegian study (54), the participants appreciated the visual elements of the application, and they also thought highly of the bidirectional contact offered by one of the applications used.

In the future, it would be interesting to find out if the adolescents respond differently to active and passive applications. Of the aforementioned mHealth applications, the majority were applications requiring input from the user (53,54,56,58) in the form of blood glucose measurements or self-reflective mood evaluation, whereas the MEMO project (59) was of totally passive nature. Either way, the thoughts of the adolescents need to be taken into consideration while designing applications.

Study protocols using mHealth

In addition to mHealth studies already published, there are at least four study protocols published in PubMed database dealing with mHealth in the health interventions among healthy adolescents. In the CHAT project (61), a mobile device (iPod touch) will be used to collect food intake data over a continuous 3-day period twice during the intervention. The actual intervention investigates the effects of tailored dietary feedback sent to the participants' mobile phones. The TXT2BFiT program (62) is aimed at improving weight management and weight-related dietary and physical activity behaviors among young adults with the help of text messages, coaching calls, and smartphone applications. However, the study protocol is not all-inclusive, and the use of applications other than text messages is unclear.

In addition to these two study protocols, one study protocol addresses binge drinking among young adults with text message intervention (63) and one study protocol aims at improving cancer prevention behaviors in adolescents and adults using a website and additional text messages (64). Quite surprisingly, all of these published study protocols relay on text messages rather than smartphone applications enabling visualization, information sharing, and game-like elements, which would possibly be more attractive to adolescents described as digital natives.

Table 3. Summary of published mHealth studies among adolescents

Reference country Age of the participants, y Trial length N (% females)	Aims of the study, study design	Intervention, device used, use of control group	Primary outcomes	Results
Australia, 2011 (56) 14–24 2–4 weeks 114 (72%)	To investigate the effects of self-monitoring on mental health outcomes, a randomized, controlled trial	Lent mobile phone was used to self-monitor current activities, location, companions, mood, responses to stressful events, alcohol and cannabis use, sleep, exercise, and diet, control group used an abbreviated version	Depression, Anxiety, Stress Scale (DASS), emotional self-awareness (ESA)	Experienced depression, anxiety, and stress decreased in both groups, emotional self-awareness increased more in the intervention group compared to the control group
Germany, 2012 (52) 13.5 (SD 2.8) 1–4 days 124 (56%)	To investigate if electronic healthcare technology can be integrated into current treatments for obese children and to find out if self-reported and objectively recorded data were consistent, an experimental study	Assessment of physical activity and eating habits with a mobile motion sensor integrated into a mobile phone with digital camera, no control group	PA (measured with motion sensor and self-administered questionnaires), energy intake (estimated from digital photos by dietician)	Measured PA was lower than self-reported, participants' estimations of energy intake were slightly lower than the objective energy intake, mobile method was highly accepted by children and adolescents
New Zealand, 2012 (59) 13–17 9 weeks 855 (68%)	To test whether a mobile phone intervention can improve subjective and objective scores of depression symptoms, a randomized, controlled trial	Two messages (text messages, video messages, animated cartoons) per day delivered to the participants' own mobile phones, access to a mobile website, control group received messages with placebo content	Program participation and usefulness (measured with self-administered questionnaires)	High adherence (75% of the intervention group and 81% of the control group viewed at least half of the messages), the program was found useful by the adolescents
Canada, 2012 (53) 12–16 12 weeks 20 (50%)	To pilot an mHealth intervention for the management of type 1 diabetes, an experimental study	Participants were supplied with an application running on an iPhone or iPod Touch with a glucometer transferring data automatically to the application, no control group	The average daily frequency of blood glucose measurement during the intervention compared with the preceding 12 weeks, change in HbA1c	Daily average frequency of blood glucose measurement increased 50%, HbA1c did not change significantly

Reference country Age of the participants, y Trial length N (% females)	Aims of the study	Intervention, device used, use of control group	Primary outcomes	Results
Norway, 2012 (54) 13–19 3 months 12 (58%)	To evaluate patients' experiences with two different phone applications used for diabetes care and to examine whether the intervention could affect disease management, an experimental study	Participants used two diabetes software applications running on lent mobile phone and discussed the use of the applications with the research team as well as participated in a semi-structure interview, no control group	Patients' experiences (interviews), disease management (measured with metabolic control)	Mobile applications were found useful, a picture-based application was appreciated more than an SMS solution, no significant changes in HbA1c
Australia, 2013 (58) 14–17 31 days 41 (61%)	To examine the relationship between differing levels of alcohol consumption and positive and negative mood in the week surrounding the drinking episodes, an experimental study	Mobile phone was used to self-monitor current activities, company, location, mood, recent stressful events and coping, alcohol and cannabis use, no control group	Daily mood and alcohol use (measured with mobile application)	Positive mood increased before and after the drinking event for those that drank intermediate amounts
USA, 2013 (60) 13–18 30 days 60 (37%)	To understand adolescents' health information needs in the context of their everyday lives and to assess how they meet these needs, a formative study	Participants were supplied with smartphones with unlimited text messaging and data access and 600 voice minutes, text messages were sent to participants three times a week, and the participants took part in a focus group discussion, no control group	Thematically summarized data derived via text messages from the adolescents, thematic analysis of the focus group discussion	Text messages were responded in 90% of cases, the sources of health information were related to parents, friends, online, mobile applications, teachers, or coaches

Gamification in health promotion

The word gamification (or gamifying) means the use of game design elements in non-game context to motivate and engage users (65). In different gamified applications (such as Foursquare), this means the collection of points, badges, and rewards and competing against one's virtual friends in statistics. Previously, gamification has been applied widely in marketing or customer loyalty programs. Unlike loyalty programs, which aim to offer economic benefits, game mechanisms are believed to add value to the service via transformation of the usage motivations and intentions (66).

Although gamification tends to be present in the media constantly, it is no magic bullet: the mere implementation of gamification mechanisms does not automatically lead to significant increases in user activity (67). In other fields of research, gamification has also been applied in teaching. However, it does not necessarily lead to better learning results (68). Despite the rather not-encouraging results in the fields of marketing and teaching, it has been suggested, that in the future, gamification will become more common as a tool in health care, since consumers use smartphones readily (69).

The academic research concerning gamification, especially in health promotion context, is extremely scarce. There are, however, game-like mobile applications designed to remodel health behavior, and since adolescents and young adults are heavy users of smartphones, they are an obvious target group for mHealth interventions. In a public health point of view, the most important target behaviors are diet and exercise, which could be easily and discreetly assessed with modern smartphones equipped with digital cameras, internet connections, and global positioning system (GPS).

To this day, only one clinical intervention using mobile gamification has been published. Since the main emphasis on this study (53) aimed at developing an mHealth application for the self-management of adolescent type 1 diabetes was not on game-like elements, it was described in more detail already in the previous subsection. However, the study design also contained rewards (in the form of purchase from Apple iTunes and App Store) distributed to participants based on their frequency of blood glucose measurements. During the intervention, altogether 161 rewards were distributed to participants, with 50% of them collecting more than ten awards and 25% of them collecting no rewards. According to the study, rewards were somewhat efficient in engaging the adolescents, but unfortunately the researchers did not report any results clarifying the possible association of the blood glucose measurements and the rewards earned. In addition, they did not have a control group using the same application with no rewards. Hence, it is impossible to say, if the increase in blood glucose measurements was because of the application itself or did the rewards motivate the adolescents to measure their blood glucose more frequently.

Since exergames (formerly video games, but nowadays games and mobile applications in general that are also a form of exercise) can increase physical activity in children (70) and are capable of inducing measurable changes in heart rate and energy expenditure (71), a promising area for future research would be the use of GPS based equipment allowing the measurement of distance and velocity during exercise. In fact, there already are several mobile applications which can be classified as GPS exergames or geosocial applications and gadgets. In a recently published editorial (72), over 30 applications designed to move people were identified and categorized as location-based game applications (such as Dokobots), location-aware fitness and sports platforms with social and gamification features (such as Microsoft HealthVault), or location-aware sports gadgets (such as Oakley Airwave GPS-enabled Goggle for skiing) and products combining GPS and heart rate monitoring of the player.

In the near future, a physical activation study targeting young men is about to be conducted in Finland. In the MOPO study (73), conscription-aged men (18 years) randomized to the intervention group will be using a gamified activation platform service monitoring and rewarding their daily activity and exercise. The gamified platform includes for example achievements supported by rewards from increased physical activity, social networking, exercise instructions, and tailored information content related to health and wellbeing. The control group participants will continue their normal lives. The main outcome is self-determined and objectively (wrist-worn physical activity monitor) measured physical activity, but also the proportion of overweight and obese participants in the intervention and control groups will be examined.

There is a growing need for attractive tools for engaging children and adolescents to improve their health. In 2010, a competition was opened to challenge innovators to develop software tools and games that drive children to eat better and be more physically active (74). More recently, The Finnish Innovation Fund Sitra started a quest for games making exercise, good dietary habits, and a healthy lifestyle a hit with Finns (75). Still, to this day, there is no scientific evidence concerning the effects of gamification on health behaviors such as nutrition or eating behaviors.

3 Aims of the study

The main objective of the study was to find out if the eating habits of adolescent athletes could be influenced using game-like smartphone application. The change in eating behavior obtained using a gamified smartphone approach was compared with that resulting from conventional dietary tutoring.

A secondary goal of the study was to examine the feasibility of the smartphone application in the study of food behavior. Based on the data collected in the present study, the activity of the adolescents in photographing their meals and the change in the activity during the intervention was assessed. In addition, sex differences and possible hindrances in the use of smartphone applications were looked into.

Hypothesis

We hypothesized that the smartphone application will affect the food behavior of the adolescent athletes. The primary hypothesis was that the game group will show more changes in their eating behavior after the intervention compared to the tutorial group. In addition, it was supposed that the adolescents will find the smartphone application suitable for monitoring their food behavior and they will use the application actively.

4 Participants and methods

4.1 Participants

Participants were basketball and soccer players from Helsinki Basketball Academy (Mäkelänrinne upper secondary school with a special educational task in sports) and Helsingin Jalkapalloklubi (HJK, Finnish soccer club). Altogether 58 participants aged 15–19 were recruited to the study via their coaches. The study protocol was approved by the University of Helsinki review board in the humanities and social and behavioral sciences in March 2013. The participants received written handouts of the study design and in addition, they were given an oral presentation describing the course of the study. Altogether 53 participants (91% of the athletes originally invited to participate) signed the informed consent and agreed to participate in the study. The participation of one participant less than 16 years was approved by his guardian. The participants were not exposed to invasive measurements and no supplements or drugs were offered to them during the study.

Of the 53 participants, 18 (34%) were basketball players and 35 (66%) were soccer players. There were 21 (40%) female and 32 (60%) male athletes in the study. Of the female athletes, seven (33%) were basketball players and 14 (67%) soccer players, whereas 11 (34%) of the male athletes were basketball players and 21 (67%) soccer players. The characteristics of the participants are described in more detail in the next section. Of the 53 participants originally recruited to the study, 41 (77%) participated in the follow-up four weeks after the baseline meeting and altogether 35 (66%) participants completed the second follow-up eight weeks after the baseline meeting.

4.2 Methods

4.2.1 General description of the study

The study was carried out as an intervention study lasting four weeks. In the beginning of the study, the participants filled out questionnaires concerning background information and their standing height (cm, without shoes, measured with stadiometer) and weigh (kg, in light indoor clothing, measured with Tanita SC-240 Body Composition Analyzer) were recorded. The background questionnaire is presented in Appendix A. The participants were asked to complete the first FFQ concerning the use of vegetables, fruits, and berries, nuts and seeds, dairy products, cereal products, fish, sweets, and drinks during the preceding week. A copy of the FFQ is presented in Appendix B. A similar FFQ was used right after the intervention period as well as after a four week follow-up. At each occasion, the weights of the participants were also measured. Those athletes unable to participate in the meetings after the intervention received the FFQs by mail.

Before the intervention, the participants were randomly assigned to game (24 participants, 45%) and tutorial groups (29 participants, 55%) using a random number generator available online (http://www.psychicscience.org/randomlist.aspx). The randomization was performed separately for all basketball players and male and female soccer players, respectively. In order to avoid motivational bias, both groups were offered a voluntary intervention period of around four weeks after the actual intervention. Altogether 16 participants (30%) took part in the voluntary intervention period.

4.2.2 Intervention

The aim of the intervention was to ameliorate the quality of the diet of the adolescent athletes by increasing the use of vegetables, fruits, and berries, improving the quality of the carbohydrates, replacing sugary soft drinks with water, and add the use of fish and nuts in the diet.

Game group

The participants randomized to the game group kept visual food journals during the 4-week study period using a smartphone application MealTracker™. The application enables creating a meal journal from pictures taken with a mobile phone. The meals in the food journals were given points if specific food items were present in the picture or mentioned in the caption. The scoring system (presented in Table 4) was on display on the front page of the application. The participants in each of the game groups competed with each other (the basketball players in their own game and the soccer players in their own). A leaderboard was visible to all members in a game group. The participants with no smartphones or with smartphones not compatible with the application were lent a smartphone with a data connection. The game display is presented in Figure 4.

The scoring system was based on positive feedback, and therefore, no negative scores were given. The given scores were based on general guidelines for healthy eating (6). In addition, prior knowledge concerning the problematics in the diets of the adolescents (8) was taken into account. By introducing classification by color for vegetables, the variety of diet and sufficient vegetable intake were taken care of. The intake of berries was emphasized because berries not only are an excellent source of vitamins and antioxidants but might also be capable of canceling the glycemic effect of sugars (76) and thus even out fluctuations in blood sugar. As fish use has been found to be less frequent than recommended (77), it was given the highest score to encourage the adolescents to choose fish dishes if possible. Fiber-rich grain products were included in the scoring system for two reasons: to improve the quality of carbohydrates in the adolescents' diet and, in addition, to make them aware of the package markings of the groceries.

Figure 4. The game display as seen in iPhone. The left side shows the leaderboard, and the rules of the competition (in Finnish) can be seen on the right side.

The daily use of skimmed milk or sour milk and other low-fat dairy products is recommended for adolescents because they are rich in calcium and vitamin D (78). Skimmed dairy products were preferred in order to improve the quality of fats in the diets of the adolescents. In addition, by giving points for drinking milk, we hoped to decrease the possible use of soft drinks as beverage at meals. Similarly, water as a post exercise drink was recommended by the scoring system to replace sports beverages usually thought highly of among adolescent athletes.

To create an opportunity to catch up with points after a couple of more passive days, weekly points were given if the participant had a proper breakfast or lunch on five out of seven days during the week. Proper breakfast or lunch was defined as a meal consisting of at least three components from the daily goals list. Daily points could be earned only once a day to avoid participants collecting points by using only one food item. Since maximum points were 19 per day and a maximum of 20 weekly points could be earned, the maximum points during the 4-week intervention were 612.

Table 4. The scoring system used in the BerryUp game group

Daily goals	Points earned
Eat a green vegetable	1
Eat a red vegetable	1
Eat a yellow/orange vegetable	1
Eat a fresh fruit	1
Eat fresh berries	2
Eat fish	3
Eat fiber-rich bread (at least 5% fiber)	2
Eat porridge, cereal (at least 10% fiber), or muesli	2
Eat nuts	2
Drink skimmed milk or skimmed sour milk	2
Drink two glasses of water after exercise	2
Weekly goals	**Points earned**
Eat proper breakfast 5 out of 7 days during the week	10
Eat proper lunch 5 out of 7 days during the week	10

The participants in the game group were emailed weekly to keep up the competition and to motivate them. After the first week of the competition, movie tickets were raffled amongst those game group members who had loaded at least seven meals to their diary. During the second week, the group members with only 20 points or less were given rewards (small bags of nuts) to encourage them to keep on photographing their meals. Finally, in the end of the competition, the participants with most points in their own game were given 15 euro gift cards to purchase berries at the market. In addition, the participants with the most effective spurts during the last week were rewarded with 4 euro gift cards for a wholegrain bread stall at the market. The participants in the tutorial group did not receive any rewards.

Tutorial group

The participants randomized to the tutorial group participated in a tutorial group meeting with 3–5 of their team mates. The tutorial group meetings were arranged separately for the basketball players and the soccer players, and girls and boys had their own group meetings. Altogether six tutorial group meetings discussing the diet of adolescent athlete were arranged in the first phase of the study. Each group meeting lasted 30–60 minutes and all the participants contributed to the discussion.

In the appointment, the participants were first asked to think of the meals and drinks they had enjoyed the day before. They then shared with the group their thoughts about sufficient number of meals in a day, good breakfast and snack choices, usual sources of fiber in their diet, their workout

drinks etc. The participants had also a chance to ask whatever they had in mind concerning diet and food choices, and in addition, relevant issues, such as the importance of eating fruits and vegetables, the benefits of high calcium intake, or the use of recovery and sport drinks, were discussed. In the end of the meeting, the participants were asked to propose one change in their eating behavior, such as "I will try to eat fish at least twice a week" or "I will try to eat breakfast every morning". They were then encouraged to say the proposed change aloud and write it down. Thereafter, obstacles hindering the changes were discussed, and the participants were encouraged to help each other in achieving their goals.

After the 4-week intervention period, all the participants had an opportunity to switch groups for another four weeks. Two more tutorial group meetings were arranged for game group members (one for basketball players and one for male soccer players) and altogether ten participants from the original tutorial group participated in BerryUp game round two. The coaches of the participants were also eligible to participate in the voluntary BerryUp game. This voluntary phase was conducted to avoid motivational bias in the tutorial group, since it was suggested that the adolescents would like to be randomized to the game group. The course of the study is presented in more detail in Figure 5.

4.3 Food consumption

Food consumption was measured using self-administered FFQs (Appendix B). The participants reported the frequency of consumption of 23 different line items over the last week. Each line item was defined by a series of foods or beverages, and the frequency of consumption was reported as times per week or times per day. Altogether three FFQs per participant were completed during the study: FFQ1 at baseline, FFQ2 after the intervention and FFQ3 after the voluntary intervention period (four weeks after the original intervention).

The FFQ was specifically designed to measure the use of preferred food items which were in line with the aims of the study. Emphasis was put on the use of vegetables, fruits, and berries, nuts, dairy and grain products, fish, candies and finger food, and beverages. The FFQ was purposefully kept light in order to avoid negligence and tiring of the participants as well as to increase participation. The main objective was not to measure accurately the use of certain foods or the supply of certain nutrients but to rank the participants according the frequency of consumption.

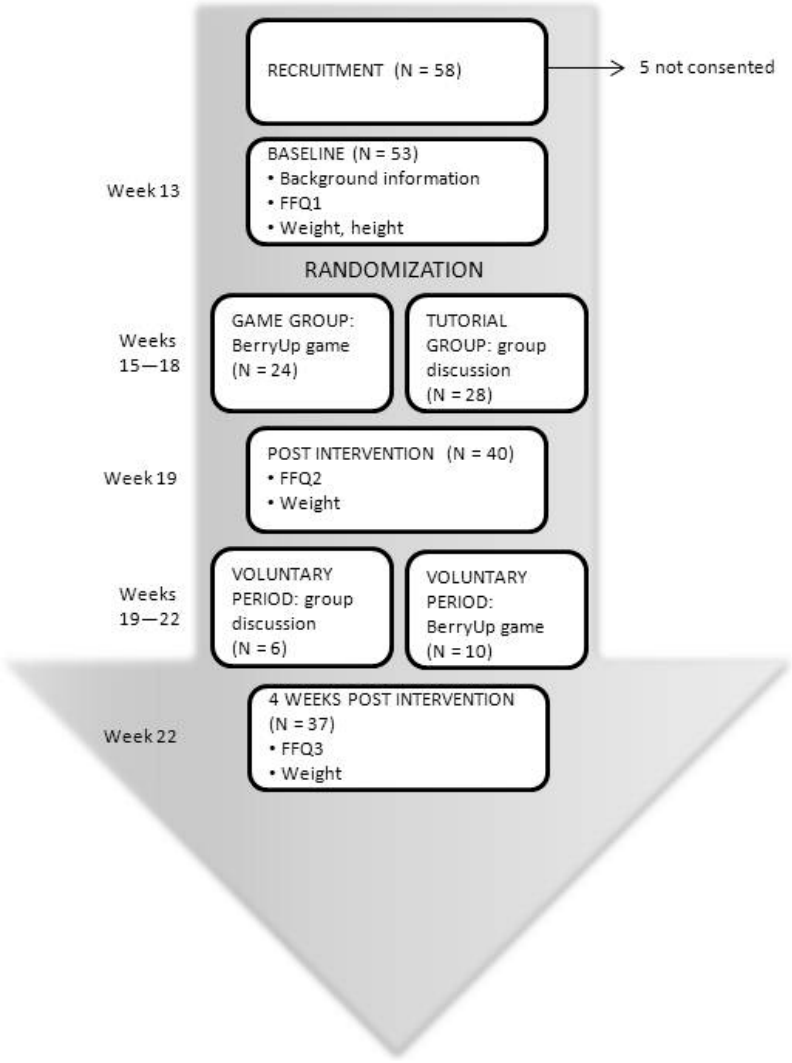

Figure 5. The BerryUp study design. Food frequency questionnaires (FFQ) were completed by the participants three times during the study.

4.4 Data handling and statistical methods

The data was stored in Excel 2010 spreadsheet (Microsoft, USA). The stored data was made comparable by transforming all of the announced frequencies of consumption into times per day. If the participant had completed both columns (times per week and times per day) and the numbers were not commensurate, the number used in analysis was judged by the participant's frequency of consumption at another time point so that these two time points were in line. Each participant's questionnaires were managed individually.

To measure changes in the diets of the adolescents, 12 variables were used. These variables as well as the nutritional objectives of the study are presented in Table 5. The use of fresh vegetables, leguminous plants, cooked vegetables, fresh fruits and berries, and fruit and berry dishes were added up to create one variable describing the use of vegetables, fruits, and berries altogether. Similarly, the

consumption of rye bread and crisp bread as well as the consumption of wholegrain bread were combined to one variable describing the use of fiber-rich grain products. The quality of carbohydrates was also measured by the use of white bread, wholegrain porridge, and rice porridge and semolina pudding. Other variables used were the consumption of skimmed milk, milk with 1% or more fat, milk in total, fish, nuts, soft drinks, and sugar-free soft drinks.

Table 5. The nutritional objectives of the intervention and the variables used to measure changes in food behavior

Nutritional goal	Variables
To increase the use of vegetables, fruits, and berries	Fresh vegetables
	Leguminous plants
	Cooked vegetables
	Fresh fruits and berries
	Fruit and berry dishes
To improve the quality of the carbohydrates	Rye bread and crisp bread
	Wholegrain bread
	Wholegrain porridge
	White bread
	Rice porridge and semolina pudding
To replace sugary soft drinks with water and skimmed milk or skimmed sour milk	Soft drinks
	Sugar-free soft drinks
	Skimmed milk
	Milk with 1% or more fat
	Milk in total
To increase the use of fish	Fish
To increase the use of nuts	Nuts

The statistical analyses were performed using IBM SPSS Statistics version 21.0 (SPSS Inc., Chicago, IL). The distribution of the variables was tested using the Kolmogorov-Smirnov test. Parametric or non-parametric tests were used depending on the distribution of each variable. Independent samples tests (independent samples t-test, Mann-Whitney U-test) were used when comparing the changes between the two groups and related samples tests (dependent samples t-test, Wilcoxon signed rank test) when investigating the changes inside the two groups. Pearson's chi-squared test was used when examining the distribution of variables in groups.

5 Results

5.1 Baseline characteristics

The baseline characteristics of the participants are presented in Table 6. Three participants (6%) studied in junior high school, two (4%) in vocational school, and one (2%) in senior secondary school for adults. The participants were mostly from upper class families (49%). The median number of siblings was 1. No statistically significant differences in age, education, number of siblings or other variables describing socioeconomic background were found between groups. One participant was excluded from the analysis because she was significantly older than the other participants.

Table 6. The baseline characteristics of the participants in the BerryUp study

Characteristics	Game group (n = 24)	Tutorial group (n = 28)	Significance	Total (n = 52)
Age, mean (SD), y	17.7 (0.81)	17.5 (0.69)	$p = 0.339$	17.6 (0.75)
Gender (% females)	42	36	$p = 0.660$	39
Sports team (% basketball players)	33	36	$p = 0.857$	35
Education (% in high school)	83	93	$p = 0.611$	89
Weight, mean (SD), kg				
Females	66.9 (9.97)	65.0 (6.61)	$p = 0.650$	65.9 (8.29)
Males	79.2 (11.95)	78.3 (8.57)	$p = 0.804$	78.7 (10.0)
Height, mean (SD), m				
Females	1.72 (0.09)	1.73 (0.08)	$p = 0.832$	1.73 (0.08)
Males	1.87 (0.14)	1.85 (0.09)	$p = 0.703$	1.86 (0.11)
BMI, mean (SD), kg/m^2				
Females	22.5 (1.96)	21.7 (1.97)	$p = 0.412$	22.1 (1.95)
Males	22.6 (1.53)	22.9 (1.77)	$p = 0.696$	22.8 (1.64)

Independent samples Mann-Whitney U-test was used for age, weight (females), and height (males). Pearson's chi-squared test was used for gender, sports team, and education. Independent samples t-test was used for weight (males), height (females), and BMI (females and males).

In 90% of the cases, the parents/a parent were responsible for the acquisition and preparation of food at home. One participant (2%) took care of his own food by himself and four (8%) participants worked in collaboration with their parents in order to acquire and prepare food. Altogether six participants (12%) had two homes. At the second home, the participants normally participated in the acquisition and preparation of food. Of all the participants, 19 (38%) ate together with their family four or five times a week, whereas seven (14%) reported participating in a family meal hardly ever.

Most of the participants (31, 61%) took nutritional supplements and the average number of daily supplements among supplement users was 2 (SD 1.22). Still, 15 (48%) of the supplement users used only one supplement. Among the participants, supplements most commonly taken were vitamin D (17, 33% of the participants), multivitamin and mineral (9, 18%), magnesium (9, 18%), and fish oil supplements (8, 16%). Other supplements taken were vitamins B and C, zinc, and iron. In addition, lactic acid bacteria products, creatine, recovery or sports drinks, and protein supplements were

taken. Eight of the participants (15%) were on a lactose-free diet and two of the participants (4%) avoided pork. One participant (2%) had a gluten-free diet and one (2%) did not eat red meat. Two of the participants (4%) had food allergies.

5.2 Participation to the intervention

All participants completed the background questionnaire as well as the first FFQ. Post intervention FFQ was completed by 40 participants (77%) and 37 (71%) completed the last FFQ (Table 7). There were no statistically significant differences in the completion of the questionnaires between the game group and the tutorial group.

Table 7. Returned forms in the BerryUp study, n (%)

	Game group	Tutorial group	Significance	Total
Background questionnaire	24 (100)	28 (100)		52 (100)
FFQ1	24 (100)	28 (100)		52 (100)
FFQ2	18 (75)	22 (79)	$p = 0.761$	40 (77)
FFQ3	16 (67)	21 (75)	$p = 0.508$	37 (71)
Feedback	4 (17)	3 (11)	$p = 0.531$	7 (13)

Pearson's chi-squared test was used for all of the variables.

The participants in the tutorial group participated rather well in the group meetings. Of the 28 participants randomized to the control group, 27 (96%) were present in their group meeting. Altogether six meetings were arranged (one for female and one for male basketball players, two for female and two for male soccer players). One participant could not participate in his tutorial group meeting because of an acute illness.

In the game group, altogether 20 participants (83% of all) loaded at least two photographs of their meals using the application. The participants earned an average of 110 points (SD 116.5) during the four-week intervention. Table 8 summarizes the points collected by the game group members. Of the 24 participants randomized to the game group, 19 (79%) earned points in the BerryUp game. The socioeconomic backgrounds of the five drop-outs, of which three were females and two males, did not differ from the active game group participants.

Table 8. Points earned in the game group

	Median	Range
Points earned in BerryUp week one	23	0–108
Points earned in BerryUp week two	10	0–95
Points earned in BerryUp week three	8	0–100
Points earned in BerryUp week four	0	0–99
Cumulative points earned in BerryUp	52	0–363

During the intervention, the median number of meals loaded to the application was 24 (range 0–142). Figure 6 shows the average number of meals loaded by the basketball and soccer players during each week of the intervention. Altogether 945 meals were loaded to the application. Of the meals loaded, 223 (24%) were breakfasts, 217 (23%) lunches, 190 (20%) dinners, 158 (17%) snacks, 104 (11%) evening meals, and 53 (6%) beverages. During the intervention period, basketball players loaded on average 68 meals to the application, whereas soccer players loaded on average 29 meals. The basketball players loaded significantly more meals to the application during weeks 1, 3, and 4 compared to the soccer players (Figure 6).

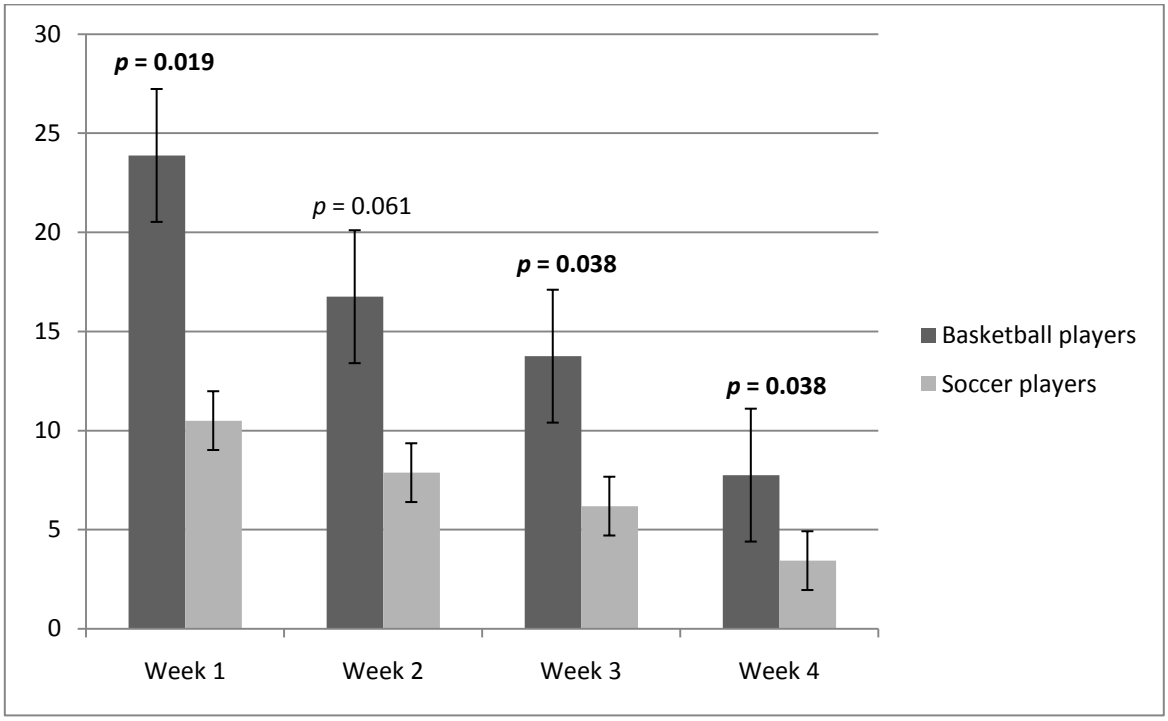

Figure 6. Average number of meals loaded to the application by basketball and soccer players during the intervention. Bars show standard errors. *p*-values calculated using independent samples Mann-Whitney U-test.

Feedback was received from seven (13%) of the participants. Of the respondents, four (57%) were members of the game group and three (43%) belonged to the tutorial group. Only two (29%) respondents reported participating in the voluntary intervention period. The majority of the respondents (80%) regarded the application as easy to use, and all of them found the application reliable. Visual food journals were regarded as a fun way to monitor one's food behavior by only one of the respondents (20%), but none of them regarded them as totally boring. Majority of the respondents (60%) felt that the rules of the game were easy to understand. All of the respondents felt that the game motivated them in changing their diets at least a little. Two respondents (40%) reported neg-

lecting to photograph meals now and then, while the rest reported no neglect by design. In addition, one respondent commented on the duration of the intervention and proposed a shorter intervention period. He also mentioned that he found the game fun and challenging as well as educational.

5.3 Food consumption at baseline

5.3.1 Food consumption among the female and the male athletes

At baseline, 15 of the female athletes (75%) and 20 of the male athletes (63%) had eaten breakfast every morning during the last week. On average, female athletes ate breakfast 6.4 (SD 1.47) times per week, whereas male athletes ate breakfast 5.7 (SD 2.00) times per week ($p = 0.164$). The female athletes had eaten an average of 4.5 (SD 0.93) meals per day during the last week whereas the average number of meals for male athletes was 3.8 (SD 1.65), ($p = 0.056$). Snacks were consumed on average 1.7 (SD 0.69) times per day among the female athletes and 1.3 (SD 0.84) times per day among the male athletes ($p = 0.05$). No differences were detected between the game and the tutorial groups.

The participants consumed vegetables (fresh and cooked vegetables), fruits, and berries (fresh and cooked) on average 3.7 (SD 2.14) times per day at baseline (Table 9). The female athletes used vegetables slightly more than the male athletes. Altogether 10 of the female athletes (50%) consumed vegetables, fruits, and berries five or more times per day, whereas the estimates for the male athletes were 8 (25%), ($p = 0.065$).

The female athletes tended to use skimmed milk more often and milk with 1% or more fat less often compared to the male athletes ($p = 0.189$ for skimmed milk and $p = 0.021$ for milk with 1% or more fat) (Table 9). Total milk consumption was less frequent among the females than the males ($p = 0.874$). The use of soft drinks and sugar-free soft drinks was quite low, but the male athletes used soft drinks significantly more often compared to the female athletes ($p < 0.001$).

The female athletes used fish on average 1.9 (SD 1.19) times per week, whereas the average consumption of fish among male athletes was 2.3 (SD 2.59) times per week (Table 9). The recommended two times a week fish consumption was reached by 11 female (55%) and 16 male athletes (50%), ($p = 0.726$). The use of nuts was similar among female and male athletes. Altogether eight female (40%) and 16 male athletes (50%) did not consume nuts at all ($p = 0.482$).

Table 9. Food consumption among female and male athletes at baseline

Food	Consumption (average times per day, SD)		
	Females (n = 20)	Males (n = 32)	Significance
Vegetables, fruits, and berries	4.8 (2.14)	3.1 (1.88)	***p* = 0.005**
Rye bread, crisp bread, and whole-grain bread	1.4 (1.01)	1.7 (1.44)	*p* = 0.720
Skimmed milk	2.1 (1.64)	1.4 (1.62)	*p* = 0.189
Milk with 1% or more fat	0.6 (1.08)	2.0 (2.53)	***p* = 0.021**
Milk in total	2.6 (1.52)	3.3 (2.93)	*p* = 0.874
Food	Consumption (average times per week, SD)		
	Females (n = 20)	Males (n = 32)	Significance
White bread	1.1 (2.19)	1.8 (2.16)	*p* = 0.096
Wholegrain porridge	2.5 (2.26)	2.1 (2.71)	*p* = 0.258
Rice porridge and semolina pudding	0.6 (1.39)	0.7 (1.33)	*p* = 0.394
Fish	1.9 (1.19)	2.3 (2.59)	*p* = 0.885
Nuts	1.3 (1.66)	1.3 (1.86)	*p* = 0.719
Soft drinks	0.5 (1.00)	2.2 (2.00)	***p* < 0.001**
Sugar-free soft drinks	0.4 (0.67)	0.8 (1.82)	*p* = 0.587

Independent samples t-test was used for one variable (vegetables, fruits, and berries) among females and males. For the other variables, independent samples Mann-Whitney U-test was used.

5.3.2 Food consumption in the game and tutorial groups

Comparison of the game and the tutorial group revealed some differences between the groups in the baseline food consumption. Females and males were examined separately because of the differences observed between the sexes. In addition, it was suspected that the interventions could have different effects on females and males.

Among the female athletes, there were statistically significant differences in the consumption of white bread and fish between the groups (Table 10). The athletes in the game group consumed white bread significantly less often compared to the tutorial group. Accordingly, the use of fish was significantly more frequent in the game group compared to the tutorial group. Of the athletes in the game group, 80% used fish more than two times a week, whereas the percentage was only 30% in the tutorial group ($p = 0.025$).

Among the male athletes, the use of vegetables, fruits, and berries was significantly more frequent in the game group compared to the tutorial group ($p = 0.015$) (Table 10). In addition, the game group members used milk with 1% or more fat significantly more often than the tutorial group members ($p = 0.044$). Respectively, the use of skimmed milk was more frequent in the tutorial group than in the game group ($p = 0.087$).

Table 10. Food consumption in the game and the tutorial groups at baseline

Food	Consumption (average times per day, SD)					
	Females			Males		
	Game (n = 10)	Tutorial (n = 10)	Significance	Game (n = 14)	Tutorial (n = 18)	Significance
Vegetables, fruits, and berries	4.8 (2.03)	4.8 (2.35)	$p = 0.986$	4.1 (2.00)	2.3 (1.34)	***p* = 0.015**
Rye bread, crisp bread, and wholegrain bread	1.3 (0.81)	1.5 (1.23)	$p = 0.671$	1.9 (1.45)	1.5 (1.45)	$p = 0.381$
Skimmed milk	2.3 (1.88)	1.8 (1.38)	$p = 0.481$	0.9 (1.54)	1.7 (1.64)	$p = 0.087$
Milk with 1% or more fat	0.7 (1.32)	0.5 (0.83)	$p = 0.657$	2.9 (2.63)	1.3 (2.28)	***p* = 0.044**
Milk in total	3.1 (1.34)	2.2 (1.65)	$p = 0.215$	3.6 (2.87)	3.1 (3.03)	$p = 0.534$
Food	Consumption (average times per week, SD)					
	Females			Males		
	Game (n = 10)	Tutorial (n = 10)	Significance	Game (n = 14)	Tutorial (n = 18)	Significance
White bread	0.3 (0.42)	2.0 (2.89)	***p* = 0.004**	2.2 (2.69)	1.4 (1.61)	$p = 0.595$
Wholegrain porridge	2.0 (1.89)	2.9 (2.60)	$p = 0.462$	2.7 (3.09)	1.6 (2.35)	$p = 0.397$
Rice porridge and semolina pudding	0.2 (0.63)	0.9 (1.85)	$p = 0.163$	0.4 (1.73)	0.8 (1.65)	$p = 0.453$
Fish	2.4 (1.33)	1.4 (0.82)	***p* = 0.048**	2.1 (1.73)	2.5 (3.14)	$p = 0.954$
Nuts	1.0 (0.94)	1.6 (2.17)	$p = 0.750$	1.6 (2.31)	1.1 (1.45)	$p = 0.822$
Soft drinks	0.4 (0.97)	0.5 (1.08)	$p = 0.957$	3.0 (2.50)	1.6 (1.24)	$p = 0.132$
Sugar-free soft drinks	0.6 (0.84)	0.1 (0.32)	$p = 0.111$	1.0 (2.53)	0.6 (1.04)	$p = 0.457$

Independent samples t-test was used for two variables (vegetables, fruits, and berries and rye bread, crisp bread, and wholegrain bread) among females. For the other variables, independent samples Mann-Whitney U-test was used.

5.4 Changes in food consumption

5.4.1 Changes in the game and the tutorial groups

Since the female and the male athletes showed different patterns of food consumption and both the game and the tutorial group received an intervention with similar objectives, the changes in food behavior occurring during the intervention were examined separately for females and males and game and tutorial group members, respectively. The participants with no points at all from the BerryUp game (n = 5, 21% of the game group, three females and two males) were excluded from the analysis to see the effect of the game. Changes occurring between the second and the third FFQ were not examined since the participants in the game and tutorial groups were unevenly distributed during the voluntary intervention period following the actual intervention. The weights of the participants did not change during the intervention.

Among the female athletes, both the game and the tutorial groups showed no statistically significant changes in food consumption during the intervention (Table 11). In the game group, there was a borderline significant decrease in the consumption frequency of milk in total during the intervention ($p = 0.066$) and a borderline significant increase in the consumption frequency of wholegrain porridge ($p = 0.084$). In addition, the game group members increased their consumption of vegeta-

bles, fruits, and berries by almost one time per day, although this change was not statistically significant. The athletes in the tutorial group showed, respectively, a borderline significant increase in the consumption frequency of fish ($p = 0.066$).

Table 11. Changes in food consumption among the female athletes during the intervention

Food	Change in consumption (average times per day, SD)			
	Game (n = 6)	Significance	Tutorial (n = 9)	Significance
Vegetables, fruits, and berries	0.94 (2.49)	$p = 0.397$	-0.75 (2.14)	$p = 0.327$
Rye bread, crisp bread, and wholegrain bread	-0.33 (0.75)	$p = 0.336$	-0.22 (1.10)	$p = 0.750$
Skimmed milk	-0.02 (1.86)	$p = 0.892$	0.14 (1.64)	$p = 1.000$
Milk with 1% or more fat	-0.86 (1.57)	$p = 0.109$	-0.44 (0.90)	$p = 0.180$
Milk in total	-0.88 (0.94)	$p = 0.066$	-0.19 (1.36)	$p = 1.000$
Food	Change in consumption (average times per week, SD)			
	Game (n = 6)	Significance	Tutorial (n = 9)	Significance
White bread	0.58 (1.43)	$p = 0.336$	0.83 (2.50)	$p = 0.667$
Wholegrain porridge	2.50 (2.95)	$p = 0.084$	0.11 (0.60)	$p = 0.564$
Rice porridge and semolina pudding	0.08 (0.49)	$p = 0.655$	-0.44 (2.13)	$p = 1.000$
Fish	0.42 (0.49)	$p = 0.102$	0.83 (1.17)	$p = 0.066$
Nuts	0.92 (2.11)	$p = 0.357$	0.39 (1.05)	$p = 0.276$
Soft drinks	0.33 (0.52)	$p = 0.157$	0.00 (0.87)	$p = 1.000$
Sugar-free soft drinks	-0.17 (0.75)	$p = 0.564$	0.22 (0.83)	$p = 0.414$

Paired samples t-test was used for one variable (vegetables, fruits, and berries). For the other variables, Wilcoxon signed ranks test was used.

Among the male athletes, a few statistically significant changes in food consumption were detected during the intervention (Table 12). The participants in the game group showed a decrease in the consumption frequency of milk with 1% or more fat and milk in total ($p = 0.028$ for milk with 1% or more fat, $p = 0.028$ for milk in total). In addition, there was a borderline significant decrease in the use of vegetables, fruits, and berries among the game group participants ($p = 0.087$).

Among the tutorial group participants, a statistically significant increase in the consumption frequency of vegetables, fruits, and berries was detected ($p = 0.024$). In addition, they increased their use of nuts ($p = 0.019$). A borderline significant increase was detected in the consumption frequency of milk in total ($p = 0.092$) and white bread ($p = 0.073$).

Table 12. Changes in food consumption among the male athletes during the intervention

Food	Change in consumption (average times per day, SD)			
	Game (n = 10)	Significance	Tutorial (n = 13)	Significance
Vegetables, fruits, and berries	-0.91 (1.51)	$p = 0.087$	1.35 (1.89)	***p* = 0.024**
Rye bread, crisp bread, and wholegrain bread	-0.06 (0.88)	$p = 0.953$	-0.32 (1.15)	$p = 0.636$
Skimmed milk	0.50 (1.68)	$p = 0.395$	0.89 (2.18)	$p = 0.192$
Milk with 1% or more fat	-2.16 (1.88)	***p* = 0.028**	0.57 (2.58)	$p = 0.374$
Milk in total	-1.47 (1.82)	***p* = 0.028**	1.17 (2.30)	$p = 0.092$
Food	Change in consumption (average times per week, SD)			
	Game (n = 10)	Significance	Tutorial (n = 13)	Significance
White bread	-0.95 (2.48)	$p = 0.236$	2.50 (4.53)	$p = 0.073$
Wholegrain porridge	0.30 (1.42)	$p = 0.496$	2.00 (6.10)	$p = 0.263$
Rice porridge and semolina pudding	-0.10 (0.74)	$p = 0.655$	-0.15 (2.19)	$p = 0.483$
Fish	0.15 (1.68)	$p = 0.798$	0.46 (4.77)	$p = 0.266$
Nuts	1.20 (3.55)	$p = 0.341$	1.50 (2.24)	***p* = 0.019**
Soft drinks	0.25 (4.10)	$p = 0.478$	0.15 (1.57)	$p = 0.677$
Sugar-free soft drinks	0.20 (0.42)	$p = 0.157$	0.00 (0.74)	$p = 1.000$

Paired samples t-test was used for one variable (vegetables, fruits, and berries). For the other variables, Wilcoxon signed ranks test was used.

5.4.2 Comparison of the changes

Among the female athletes, changes in food consumption did not differ much between the two groups. The consumption frequency of wholegrain porridge increased by 2.50 times per week in the game group, whereas the increase in the tutorial group was only 0.11 times per week (Table 13). This difference was statistically significant ($p = 0.028$). The changes in the consumption of the other food items did not differ significantly between the two groups.

Among the male athletes, different changes in food consumption were detected between the game and the tutorial groups. The consumption of vegetables, fruits, and berries decreased in the game group and increased in the intervention group ($p = 0.005$). Similarly, there was a decrease in the consumption of milk with 1% or more fat and milk in total among the game group participants, whereas the participants in the tutorial group increased their use of milk with 1% or more fat and milk in total ($p = 0.020$ for milk with 1% or more fat and $p = 0.009$ for milk in total). A borderline significant difference ($p = 0.067$) was detected when examining the changes in white bread consumption: the participants in the game group decreased their use of white bread, whereas among the tutorial group participants the consumption of white bread increased.

Table 13. Changes in food consumption in the game and the tutorial groups during the intervention

Food	Change in consumption (average times per day, SD)					
	Females			Males		
	Game (n = 6)	Tutorial (n = 9)	Significance	Game (n = 10)	Tutorial (n = 13)	Significance
Vegetables, fruits, and berries	0.94 (2.49)	-0.75 (2.14)	*p* = 0.184	-0.91 (1.51)	1.35 (1.89)	***p* = 0.005**
Rye bread, crisp bread, and wholegrain bread	-0.33 (0.75)	-0.22 (1.10)	*p* = 0.720	-0.06 (0.88)	-0.32 (1.15)	*p* = 0.306
Skimmed milk	-0.02 (1.86)	0.14 (1.64)	*p* = 0.948	0.50 (1.68)	0.89 (2.18)	*p* = 0.694
Milk with 1% or more fat	-0.86 (1.57)	-0.44 (0.90)	*p* = 0.452	-2.16 (1.88)	0.57 (2.58)	***p* = 0.020**
Milk in total	-0.88 (0.94)	-0.19 (1.36)	*p* = 0.185	-1.47 (1.82)	1.17 (2.30)	***p* = 0.009**
Food	Change in consumption (average times per week, SD)					
	Females			Males		
	Game (n = 6)	Tutorial (n = 9)	Significance	Game (n = 10)	Tutorial (n = 13)	Significance
White bread	0.58 (1.43)	0.83 (2.50)	*p* = 0.719	-0.95 (2.48)	2.50 (4.53)	*p* = 0.067
Wholegrain porridge	2.50 (2.95)	0.11 (0.60)	***p* = 0.028**	0.30 (1.42)	2.00 (6.10)	*p* = 0.792
Rice porridge and semolina pudding	0.08 (0.49)	-0.44 (2.13)	*p* = 0.778	-0.10 (0.74)	-0.15 (2.19)	*p* = 0.321
Fish	0.42 (0.49)	0.83 (1.17)	*p* = 0.747	0.15 (1.67)	0.46 (4.77)	*p* = 0.443
Nuts	0.92 (2.11)	0.39 (1.05)	*p* = 0.714	1.20 (3.55)	1.50 (2.24)	*p* = 0.950
Soft drinks	0.33 (0.52)	0.00 (0.87)	*p* = 0.477	0.25 (4.10)	0.15 (1.57)	*p* = 0.330
Sugar-free soft drinks	-0.17 (0.75)	0.22 (0.83)	*p* = 0.385	-0.20 (0.42)	0.00 (0.74)	*p* = 0.465

Independent samples t-test was used for one variable (vegetables, fruits, and berries and rye bread, crisp bread, and wholegrain bread) among both females and males. For the other variables, independent samples Mann-Whitney U-test was used.

6 Discussion

6.1 Food consumption at baseline

Breakfast

It seems that among the BerryUp participants, breakfast was eaten fairly regularly: at the baseline, 75% of the female athletes and 63% of the male athletes had eaten breakfast every morning during the last week. In comparison, in the LATE-project (8), 67% of the teenage girls and 63% of the teenage boys ate breakfast every weekday. Among adult population, eating breakfast seems to be more frequent compared to the youth: 89% of women and 88% of men aged 25–34 had breakfast at least once during two interview days in the FINDIET 2007 survey (77).

It is probable that the BerryUp participants ate breakfast regarding of the day of the week, since the FFQ used in the BerryUp study assessed breakfast eating during the last seven days and thus included both weekdays and weekends. Previously, it has been suggested that among adolescents, eating breakfast is more common on Saturdays and Sundays than on weekdays (8).

The results from international studies examining breakfast eating among adolescents have been somewhat inconsistent. In a Japanese study, the proportion of adolescents who did not eat breakfast regularly was only about 10% among both females and males (79), whereas in a Canadian study examining eating habits of young female athletes (80), the majority of the participants did not eat breakfast regularly. On the other hand, in a Belgian study (81), all athletes had daily breakfast.

Number of meals

In the BerryUp study, the average number of meals eaten at baseline differed between sexes: the female athletes ate on average 4.5 meals per day, whereas the male athletes had on average 3.8 meals per day. Since male athletes have greater body mass compared to female athletes and thus require more energy, it is noteworthy that the female athletes ate more often during the day than the male athletes. In addition, it has been shown that underreporting is more common among women than among men (82,83). However, since food intake was measured using FFQs, it is possible that the male athletes consumed bigger portions on fewer occasions compared to the female athletes. It is also possible that there were interpretive challenges especially apparent among the male athletes in completing the FFQ.

Both the female and the male athletes in the BerryUp study failed to meet the recommendations set in the Finnish Olympic Committee's nutrition guidebook for athletes (84). The guidebook recom-

mends 5–7 meals per day consisting of breakfast, lunch, dinner, and snacks. It is remarkable, that the adolescent athletes with huge energy requirements eat considerably less often than adult Finns, who according to the FINDIET 2012 survey ate on average 6.3 meals per day on workdays (77). In a Canadian study (85), however, athletes ate on average 4.8 times per day and only few dietary variations were discovered between sexes.

Consumption of different food items

The participants in the BerryUp study consumed vegetables, fruits, and berries rather often, and the difference between sexes was parallel to other studies reporting higher intake of fruit and vegetables among females (86). At baseline, the female athletes consumed vegetables, fruits, and berries on average 4.8 times per day, whereas among the male athletes the average consumption was 3.1 times per day. According to the results of the LATE-project (8), nearly all of the participants ate vegetables daily, but only 20% of boys and 39% of girls consumed fruits daily. In the BerryUp study, 50% of the female athletes and 25% of the male athletes reached the recommended total consumption of five times a day. In comparison, in a Brazilian study (87), only 23% of the participants consumed five servings of fruits and vegetables daily, and the proportion of participants not consuming fruits daily was greater among boys than girls. In the BerryUp study, the proportion of females not consuming fruits and berries daily was 0%, and the respective proportion among males was 7%.

The female athletes consumed milk with 1% or more fat significantly less often compared to the male athletes. This might be due to the fact that women are more likely to follow a special diet or restrain their eating behavior (86). The use of skimmed milk or milk in total together did not differ significantly between sexes in the BerryUp study. Altered bone mineral density is one of the components of the female athlete triad (88), a syndrome prevalent especially among females participating in sports that emphasize leanness or body weight. Since dairy products are a good source of calcium, the use of milk should be encouraged among adolescent athletes whose bone mass is still increasing.

The consumption of soft drinks was almost non-existent among the female athletes, whereas the male athletes consumed soft drinks 2.2 times per week. In a meta-analysis combining the results from 88 studies (89) soft drink intake was associated with lower intakes of milk and calcium. However, the male athletes in the BerryUp study consumed milk on average 3.3 times per day suggesting that the soft drink consumption did not affect the milk consumption. The National Nutrition Council in Finland recommends using about half a liter of liquid dairy products daily (6); if a portion is assumed to be 1.5 dl, both the female and the male athletes in the BerryUp study could increase their

milk consumption to reach the desired level. However, since FFQ was used to measure milk consumption, the actual amount of milk enjoyed is hard to estimate. In addition, the FFQ assessed only the consumption of milk and sour milk, whereas the use of cheese, yoghurt, curd, and other sources of calcium were not assessed.

At baseline, there were some differences between the game and tutorial groups in food intake. Among the female athletes, white bread was consumed significantly less often and fish was consumed significantly more often in the game group compared to the tutorial group. Among the male athletes, participants in the game group used vegetables, fruits, and berries as well as milk with 1% or more fat significantly more often compared to the participants in the tutorial group. These differences at baseline occurred solely by chance, since the group division was performed randomly. Unfortunately, because of the small sample size, the effect of the baseline could not be controlled in the analysis.

6.2 Changes in food consumption

Game group

The BerryUp study showed that gamification can trigger changes in food consumption among adolescent athletes. The changes were more visible among the male athletes. Among the female athletes, consumption of vegetables, fruits, and berries, for example, was rather high at baseline, and there was no need for major changes in food consumption patterns. Although the highest points were given if fish was visible in the food journal, the consumption of fish did not change during the intervention. This suggests that the scoring system did not have such a large influence over the adolescents. On the other hand, the use of fish was quite frequent already at baseline.

Among the female athletes in the game group, no statistically significant changes were detected during the intervention. There were, however, some positive changes. For example, the consumption frequency of wholegrain porridge increased among the game group participants. In the BerryUp game, two daily points were given when porridge was visible in the visual food journal. It was not stated in the rules of the game that the porridge consumed should be wholegrain porridge, but no increase in the consumption of rice porridge and semolina pudding was seen.

In addition to changes in porridge consumption, the female athletes decreased their consumption of milk in total. One of the objectives of the game was to replace sugary soft drinks with water and skimmed milk or sour milk. Soft drinks were, however, used extremely rarely at baseline making it difficult to decrease their consumption. Of the milk used at baseline, only a small portion was milk

with 1% or more fat. The decrease in the total amount of milk is a negative change, since adolescents need calcium to increase their bone mass and the baseline consumption was not especially high. The decrease in the consumption of skimmed milk was close to zero, whereas the decrease in the consumption of milk with 1% or more fat was 0.86 times per day. This suggests that the decrease in the consumption of milk in total was mainly due to the decrease in the consumption of milk with 1% or more fat. Neither of the changes were, however, statistically significant on their own.

Among the male athletes in the game group, a decrease in the consumption of milk with 1% or more fat and milk in total was detected. As already discussed, a decrease in the use of milk can be seen as a negative change. However, among the male athletes, it can be safely stated that the decrease in the consumption of milk in total was mostly because the decrease in the consumption of milk with 1% or more fat. In fact, the consumption of skimmed milk seemed to increase during the intervention, although the increase was not statistically significant. The male athletes also decreased their consumption of vegetables, fruits, and berries during the intervention. However, the baseline level was remarkably high (almost 2-fold compared to the tutorial group).

It has been suggested that the efficacy of mHealth could be affected by gender (90): men and women might differ in their dietary self-efficacy, information sources, and desired topics in future mHealth interventions. In more traditional intervention studies, somewhat conflicting results have been obtained. Reading et al. (91) detected no significant improvement in the nutrition knowledge of male ice hockey players two weeks after the intervention, but on the other hand, Chapman et al. (92) were able to demonstrate a significant difference in female football players' nutrition knowledge between experimental and control groups after nutrition education. They did not, however, improve their dietary intake or food choices. In the BerryUp study, nutrition knowledge was not tested.

Tutorial group

Group meetings arranged were effective and able to bring about a change in the diets of the adolescents. More changes were detected in the diets of the male athletes compared to the female athletes. However, already at baseline, the female athletes' diets were of good quality. It seems that the adolescent athletes are motivated to change their diets, but they need to be able to decide their own objectives.

Among the female athletes in the tutorial group, no statistically significant changes were detected during the intervention. They did, however, increase their consumption of fish. At baseline, the fe-

male athletes in the tutorial group consumed fish less frequently compared to the athletes in the game group. Although the basis for the tutorial group conversations was similar in all of the meetings, the course of the conversation was very much influenced by the initiatives of the adolescents. This could have impacted food consumption. For example, the use of fish was discussed in the group meetings with the female athletes quite much and many of them decided in the meeting to increase their fish consumption. One of the best features in the group meetings was the possibility to validate the objectives of the intervention to the participants.

Among the male athletes, the consumption of vegetables, fruits, and berries and nuts increased during the intervention. Since the tutorial group members had originally lower levels of vegetable, fruit, and berry intake, they could increase their consumption significantly. The use of vegetables in diet was thoroughly discussed in all of the group meetings, since many of the male athletes seemed to have a rather negative attitude towards vegetables and salads. Fruits were discussed as practical and healthy snacks. Nuts were discussed in general in all of the group meetings, but in one group, the discussion was especially thorough. The increase in the use of nuts was expected since nuts are a food item that is easily available and they can be added to one's diet without making extreme changes.

The male athletes in the tutorial group also increased their use of milk in total. On the basis of the figures, it seems that there was an increase in the use of skimmed milk and milk with 1% or more fat. In the group meetings, milk consumption was not discussed much, since the emphasis was mostly on the consumption of vegetables. The use of recovery and sports drinks was, however, discussed extensively with the male athletes in all of the group meetings, and the use of milk as a recovery drink was suggested to them. In addition, the tutorial group participants increased their consumption of white bread. Since the discussions in the group meetings revolved mostly around vegetable intake, sports drinks, and practical and healthy snacks, the quality of carbohydrates in the diet might have been brushed aside.

Comparison of the intervention methods

Among the female athletes, the two interventions had quite similar effects on the adolescents. The consumption frequency of wholegrain porridge increased significantly more in the game group compared to the tutorial group. In other variables, no significant differences were detected. Among the male athletes, significant differences between the game and the tutorial groups were detected in the change in consumption frequency of vegetables, fruits, and berries, milk with 1% or more fat,

and milk in total. In addition, the participants in the game group decreased their consumption frequency of white bread, whereas the participants in the tutorial group increased theirs.

BerryUp game focused on positive feedback and no negative scores were given despite of possible unhealthy food choices. That is to say, despite of the fact that the game group members did not get any feedback (scores) on their consumption of white bread, they managed to decrease the consumption frequency of white bread, whereas the consumption frequency increased in the tutorial group. It has been suggested that positive messages are more effective in inducing health behavior change (93), but on the other hand, in a more recent study investigating adults (94), it was not clear if positively framed messages were more persuasive than negatively framed messages. The decreased consumption frequency of white bread among the game group members was not compensated for by the increase in the use of rye bread, crisp bread, and wholegrain bread. The consumption of white bread was similar in the two groups at baseline.

Although the two interventions had common goals, they differed in goal setting. First of all, in the tutorial group, the participants were encouraged to set their own nutritional goals, whereas the goals of the game group were defined by the study personnel in the rules of the game. In addition, the two interventions differed in the number of nutritional goals. In the tutorial group meetings, the participants named one nutritional goal for themselves, but the game group participants had as many as 13 nutritional goals. This might have been all too much, albeit many of the goals could have been achieved by one or two changes (for example, by eating vegetables, fruits, and berries diversely, altogether five out of 13 goals could be met).

6.3 Methodological issues and limitations of the study

Representativeness of the sample

Since the participants were recruited as teams, the sample of this study is not representative of the whole target population (adolescent athletes). It has been shown that the sports disciplines affect the nutrition knowledge, attitudes, and practices of athletes (95) and, in addition, the coaches and the parents have a huge effect on the nutritional practices of the adolescent athlete (12), although not all the advice given by coaches are beneficial (96). In the BerryUp study, the three recruited sports teams had coaches dedicated to their teams, and at least in the case of the basketball players, also the parents were highly interested in their children's well-being and nutrition. The nutritional knowledge of the coaches and nutritional advice given by them were not assessed in the study.

The background characteristics of the participants were not representative of the target population. Majority of the participants studied in high school and were from upper class families. Especially the basketball players were a highly selected group since they studied in the Mäkelänrinne High School, which has a special educational task in sports. This means that the basketball players were among the best athletes in their own age group, which probably affects their food choices and diets. There is a possibility that the results obtained would have been more persuasive had the BerryUp study focused on the basketball players solely. In addition, it has to be taken into account that the participants might have wished to impress the study personnel as athletes with healthy diets. In the second FFQ, they were already used to the situation and the possibility of misreporting is less likely. This might explain the considerably high consumption of vegetables, fruits, and berries at baseline as well as some of the changes that occurred during the intervention.

Of the 58 athletes originally recruited to the study, 53 (91%) decided to participate. No background information was collected from the athletes not participating in the study, but most of them were not reached because they did not practice with the team any more or participated in the matriculation examination and did not have enough spare time. Although soccer has lost its popularity among Finnish children and adolescents, it is still the number one sports among 3–18 year olds (97). The representativeness of the study would have benefited from a broader span of sports disciplines. In the BerryUp study, the proportion of females were 39% (basketball) and 40% (soccer), whereas according to the Finnish Sports Federation, 31% of basketball players and 21% of soccer players are females (97). In conclusion, the BerryUp study sample was fairly representative of the adolescent athletes living in the Helsinki metropolitan area.

Of the 53 athletes consented, 40 (77%) completed the FFQ after the intervention. There was a minor, yet not significant difference in the number of completed FFQs between the game and the tutorial groups. Hence, it is likely, that the difference occurred by chance. However, it is possible, that the game group members not participating in the BerryUp game actively thought that they were not supposed to complete the second FFQ because of their inactivity. In addition, four of the male soccer players joined another soccer club before the second FFQ was completed. Compared to other mHealth studies covered in section 2, compliance in the BerryUp study was rather high: only one study reached a participation rate over 90% (54), whereas in the other studies, participation rates fluctuated between 39% (58) and 70% (56).

Use of technology

One of the problems arising in mHealth studies is the use of reasonably high-technology devices. This can lead to selection bias, as not everyone in the target population possesses a smartphone or a tablet PC. For example, in the MEMO study (59), 371 (28%) participants were excluded from further analysis due to several reasons, one of which was difficulties viewing the video messages on their phones. In the BerryUp study, however, smartphones were lent for those who had no access to one. Still, the use of a borrowed device may have affected the participants' activity in the game, since it is impractical to carry two mobile phones. The participants may have also experienced problems with non-familiar smartphones, although no such problems were reported.

It can be argued that the adolescents already use mobile phones too much, and thus it is not justified to make them photograph their meals and carry smartphones with them all the time and everywhere. It seems that adolescents whose fathers have low educational or socioeconomic status or who are from non-nuclear families use more mobile phones compared to adolescents from higher socioeconomic groups (98). In addition, poor diet is more prevalent among lower socioeconomic groups (99). Thus, mobile applications aimed at improving adolescents' health could reach the adolescents who need them most. On the other hand, ICT use can be associated with sleep disturbances, reduced performance, or mental health problems (100).

Statistical power

Since the BerryUp study was a pilot study, no power calculations were performed beforehand. The target sample size was estimated to be large enough to be able to detect at least some of the possible changes in the diets of the adolescents. To achieve a statistical power of 80%, there should have been at least ten female athletes in both the game and the tutorial groups (calculated online at https://www.dssresearch.com/KnowledgeCenter/toolkitcalculators.aspx). Females were slightly more likely to be inactive in the game: three out of ten females (30%) did not earn any points during the intervention, whereas among males, the number of inactive participants was two out of 14 (14%). Hence, to get at least ten active females, 15 females should have been recruited to the game group. For males, the respective number of recruits would have been 12. Taking into account the proportion of the participants who completed the second FFQ and assuming that they were distributed evenly between the two groups, altogether 70 participants would have had to be recruited to the study to achieve statistical power of 80%.

Usability of the application

When looking at the meals loaded to the application, it can be seen that the intervention period was indeed too long. During weeks one and two of the intervention, an average of over ten meals per participant were loaded to the application, whereas the respective numbers during weeks three and four were substantially smaller. On the other hand, some of the participants kept on loading pictures for the whole intervention period and earned a notable amount of scores. During weeks 1,3, and 4, the basketball players loaded significantly more meals to the application compared to the soccer players, although the number of meals loaded among the basketball players also decreased as time passed.

It seems that the basketball players were more involved in the intervention compared to the soccer players. One of the possible explanations is that the parents of the basketball players were invited to a meeting by the basketball academy prior to the intervention. As it has already been discussed, engaging parents might have a positive effect on intervention outcomes (39). In addition, the basketball players were recruited via their school, whereas the soccer players were from different schools and participated in the intervention as a sports club team. The basketball players were likely to run into each other during school days and maybe even discuss their food choices. They might, in addition, have had a more profound team spirit and they might have received more social support from peers, which can be an important feature in health interventions (101).

Adolescents' possibilities to influence their diets

It can be pointed out that since most of the adolescents in the BerryUp study ate at least once a day in school and when eating at home, a parent/parents usually prepared the food, they did not have a lot of possibilities to influence their diets. However, according to School Health Promotion Study (102), 50% of females and 48% of males studying in upper junior high school in Helsinki metropolitan area have 10–29 euros per week to be used however they like. Since young athletes need a lot of energy, it is likely that they spend at least a part of this money to buy snacks or food. In addition, the tutorial group members mentioned during the group meetings that despite the fact that they do not prepare their own food, they often express their wishes regarding the food served at home to their parents. It is, however, true that at school lunch the adolescents do not have much choice, but still, they can make a big difference to their diets by eating all the parts of the school lunch offered.

FFQ

The FFQ used was not very thorough. It was designed to measure only the food items the intervention was supposed to have an effect on, such as the use of soft drinks and nuts. In fact, since the FFQ only measured food consumption on quite a rough level, the changes detected were both few and substantial. A more detailed FFQ would have probably offered more statistically significant yet minor changes. That is, with the FFQ used, no data describing the actual consumption of food items (g/d) could be obtained. Instead, only relatively large changes in the diets of the participants could be detected by the FFQ. This made it hard to verify the effects of the intervention.

In a review summarizing the validity and reliability of child/adolescent FFQs, the highest average validity correlations were obtained when the questionnaire did not assess portion size, measured a short time span (i.e. previous day/week), was of medium length (20–60 items), and was not administered to the child's parents (103). Although the FFQ used in the BerryUp study was not validated, it met all the above-mentioned criteria. However, despite the FFQ being reasonably short and simple to complete, there were plenty of participants with incoherent responses. These incoherencies were managed individually as described in section 4.3. Still, they could have influenced the results obtained.

6.4 Future research

It has been suggested that the use of mobile communication devices in managing treatment could save up to 99 billion € in healthcare costs in the European Union by 2017 (104). Hence, it is quite surprising that there are less than ten published intervention studies using mHealth, practice of medicine or public health supported by mobile devices, as a tool in health promotion interventions among adolescents. So far the studies published have quite small sample sizes, inadequate intervention components, or are at least partly of qualitative nature. The BerryUp study was designed to investigate the effects of gamification on the diets of adolescent athletes. However, because of the small sample size and rather long intervention period the BerryUp study was, like other mHealth studies, not able to show strong effects. Still, it offered important knowledge regarding future intervention studies applying mHealth.

In future interventions using gamification the duration of the intervention period should be restricted to avoid tiring the participants. It seems that a suitable duration of the intervention would be around two weeks. In addition, the use of tutorial group meetings could be combined to the gamified intervention to increase the participants' inner motivation and to get a chance to justify the objectives of the intervention. The tutorial group meetings could also be beneficial in building the

team spirit and enhancing social support. When studying adolescents, the role of the parents should not be forgotten, although the young already have their own opinions. Idols or role models, such us professional athletes, participating in the game could increase the adolescents' adherence to the game: in a health intervention carried out in the USA the youth themselves suggested the use of role model delivered messages (105).

It has been shown that individually-adapted health behavior change programs tailored to the individual's readiness for change, interests, and preferences are effective in increasing levels of physical activity (106) and trigger changes in the participants' diets (107). In the future, gamified mHealth interventions could adapt to individual needs and preferences. For example, in the BerryUp game, the participants could have been divided into game groups on the basis of their individual dietary goals. These goals could have been defined in an interview or a tutorial group meeting led by a nutritionist. On the other hand, game groups mixing sports teams could have disturbed the team spirit especially visible among the basketball players.

It is possible that the gamified intervention in the BerryUp study was not able to bring about substantial changes because the diets of the adolescent athletes were already of good quality in the beginning of the study. A more suitable target group for gamified nutritional interventions could be for example boys studying in vocational school, since it has been shown that their diets are poor compared to boys studying in high school (23). On the other hand, the BerryUp study might have benefitted from using athletes as participants, since gamified interventions require competitive spirit. In addition, it is possible that males express more rivalry compared to females (108). Thus, more research is needed regarding the effects of gamification among different genders. Furthermore, it would be important to find out if the effects are more prominent among younger children compared to adolescents.

There is no denying that nutrition plays an important part in the development and success of athletes. Since adolescent athletes require huge amounts of energy and nutrients, the quality of their diets is not irrelevant. There is, of course, a time and a place for unhealthy snacks or meals, but for an athlete to become one of the best in his sport, the foundations of his diet should be solid. Brett Hull, a former NHL star whose career total of 741 goals is the third highest in NHL history (109), has once stated that "At age seventeen, Wayne Gretzky and Mario Lemieux were headed for greatness. At age seventeen, I was headed for donuts." Imagine, how good a player Hull would have become, if he had had a chance of getting nutritional education.

7 Concluding remarks

Gamification can influence food behavior among adolescent athletes. In this study, the participants' food choices were close to recommendations already at the beginning of the intervention, which made it difficult to show the effects of the gamified application. However, among the male athletes, the gamified application was able to trigger changes in food behavior. The female athletes' diets were initially of good quality, and no major changes in food consumption patterns were detected during the intervention.

The tutorial group meetings with personal goal settings were also effective. Again, more changes were detected among the male athletes compared to the female athletes. In the group meetings, several different topics were discussed, but in general, the male athletes were interested in sports and recovery drinks, vegetables, and easy as well as healthy snacks, whereas the female athletes were keen to reflect their use of fish and milk and talk about their eating habits.

Both the game and the tutorial group participants liked the intervention in general. The gamified application was thought to be easy to use, reliable, motivating, fun, challenging, and educational. The number of meals loaded to the application decreased during the intervention, and the basketball players were more active in using the visual food journals compared to the soccer players. The higher activity among the basketball players could be due to the participation of their parents in the intervention. In addition, as they studied in the same school, they were more likely to run into each other during school days and maybe even discuss their food choices.

In the future, gamified interventions should have shorter durations. It seems that a suitable duration in adolescents' interventions could be around two weeks. The role of parents, peers, team mates, coaches, and role models should not be forgotten. Group meetings discussing healthy diet could be combined to the gamified intervention to increase the adolescents' inner motivation and to build team spirit. In addition, tailored intervention objectives could be designed together with the participants to empower them.

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Appendix A: Background questionnaire

Tutkittavan tunnus

BERRY UP – Taustatietokysely

Hyvä nuori!

Pyydämme sinua ystävällisesti vastaamaan seuraaviin kysymyksiin. Ympyröi oikea tai kaikki oikeat vastaukset. Kaikki kyselyllä kerätty tieto on luottamuksellista ja sitä käsitellään vain tässä tutkimuksessa. Tutkimuksesta raportoitaessa ei käytetä tunnistamisen mahdollistavaa tietoa.

Lomakkeen täyttöpäivämäärä |___|___|___|___|___|___|
p p k k v v

---

1. Tutkittavan nimi _____

2. Syntymäaika |___|___|___|___|___|___|
p p k k v v

3. Puhelinnumeroni tietojen mahdollista tarkistusta varten _____

4. Kouluni _____Luokka_____

5. Urheilujoukkue/joukkueet, johon kuulun:

_____

_____

6. Painoni |___|___|___| kg

7. Pituuteni |___|___|___| cm

8. Äitini syntymävuosi |___|___|___|___|

9. Isäni syntymävuosi |___|___|___|___|

10. Äitini ammatti _____

11. Isäni ammatti _____

Appendix A: Background questionnaire

12. Onko kodissasi / kodeissasi muita sisaruksia, jotka asuvat ainakin osan aikaa samassa taloudessa? Mikäli on, merkitse sisarusten lukumäärä.

1 Ei
2 Kyllä
   a. alle kouluikäiset (0-6-vuotiaita): ____ lasta
   b. kouluikäiset (7-17-vuotiaita): _____ lasta
   c. täysi-ikäiset (18-vuotiaat ja sitä vanhemmat) _____ lasta

13. Kuka/ketkä vastaavat pääasiassa kotisi ruokahuollosta? Mikäli sinulla on useita koteja, ilmoita ruokahuollosta vastaavat erikseen eri kodeille.

_____

_____

14. Kuinka usein perheenne syö yhteisen aterian arki-iltoina?
Yhteinen ateria tarkoittaa, että vähintään toinen vanhemmista syö lapsen tai lasten kanssa yhtä aikaa.

1 ei juuri koskaan
2 kerran viikossa
3 kaksi tai kolme kertaa viikossa
4 neljä tai viisi kertaa viikossa

15. Nimeä säännöllisesti käyttämäsi ravintovalmisteet sekä niiden määrät (esim. MiniSun 10 mikrog, 1 tabletti/vrk).

Valmisteen nimi	Annos/ vrk	Annos/viikko

☐ Haluan saada tietoa tutkimustuloksista sähköpostitse osoitteeseen

_____

_____

KIITOS VASTAUKSISTASI!

Appendix B: Food frequency questionnaire (FFQ)

Tutkittavan koodi:

RUOANKÄYTÖN KYSELYLOMAKE

Hyvä nuori urheilija!
Pyydämme sinua ystävällisesti vastaamaan seuraaviin kysymyksiin. Kaikki kyselyssä kerätty tieto on luottamuksellista ja sitä käsitellään nimettömänä. Jos sinulla on kysyttävää tutkimuksesta tai kyselyn täyttämisestä, voit ottaa yhteyttä ravintotutkijaan: Henna Vepsäläinen, puh. 044 358 1467.

Kiitos osallistumisesta tutkimukseen!

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1. Lomakkeen täyttöpäivä |____|____| / |____|____| / |____|____|____|____|
pv kk vuosi

2. Noudatatko erityisruokavaliota tai välttämisruokavaliota? Ympyröi yksi tai useampi vaihtoehto.

1 en noudata erityisruokavaliota tai välttämisruokavaliota
2 laktoositon tai vähälaktoosinen ruokavalio
3 gluteeniton ruokavalio (vältän vehnää, ruista ja ohraa)
4 kasvisruokavalio, joka sisältää
  maitoa
  b kalaa
  c kananmunaa
  d ei mitään yllä olevista
5 ruoka-allergia tai -yliherkkyys, mitä ruokia vältät?

____

6 muu ruokavalio, mikä____

3. Kuinka monta kertaa päivässä tai viikossa olet syönyt seuraavia aterioita __viimeisen viikon aikana__? Mikäli et ole syönyt kyseistä ateriaa lainkaan, merkitse 0 kohtaan ”kertaa viikossa”. Täytä vain yksi sarake riviä kohti.

	Kertaa viikossa	**Kertaa päivässä**
Aamiaisen		
Pääaterian (esim. lounas, päivällinen, illallinen)		
Välipalan (esim. päivävälipala, iltapala)		

Appendix B: Food frequency questionnaire (FFQ)

4. Kuinka usein olet syönyt seuraavia ruokia viimeisen viikon aikana? Ilmoita kunkin elintarvikkeen kohdalla, kuinka monta kertaa yhteensä päivässä tai viikossa olet käyttänyt kyseistä elintarviketta. Mikäli et ole käyttänyt elintarviketta lainkaan, merkitse 0 kohtaan ”kertaa viikossa”. Täytä vain yksi sarake riviä kohti.

	Kertaa viikossa	**Kertaa päivässä**
KASVIKSET, HEDELMÄT JA MARJAT		
Tuoreet kasvikset (esim. vihersalaatti, porkkanaraaste, kurkku, tomaatti, paprika)		
Herne, pavut, linssit, soija (esim. tofu, falafel)		
Kypsennetyt kasvikset (lisukkeena, kasvisruoissa)		
Tuoreet hedelmät ja marjat		
Hedelmä- ja marjaruoat (esim. kiisseli ja salaatti)		
PÄHKINÄT, MANTELIT JA SIEMENET		
Pähkinät, mantelit ja siemenet (maustamaton)		
MAITOVALMISTEET		
Rasvaton maito ja piimä		
Ykkös-, kevyt ja täysmaito ja -piimä		
VILJAVALMISTEET		
Valkoinen riisi ja pasta		
Tumma riisi ja pasta		
Ruisleipä, näkkileipä, hapankorppu		
Vaalea täysjyväleipä (esim. sekaleipä, grahamsämpylä tai -paahtoleipä)		
Valkoinen leipä (esim. patonki, ranskanleipä, rieska, vehnäsämpylä)		
Täysjyväpuuro, -muro ja -mysli (esim. kaurahiutalepuuro, All-Bran, Weetabix)		
Riisi- ja mannapuuro, riisi- ja maissi-hiutalemuro (myös suklaiset murot ja muromysli)		
Suolainen piirakka (esim. karjalanpiirakka, lihapiirakka, pasteija)		
Makea leivonnainen (esim. pulla, munkki, kääretorttu, kakku, piirakka, ohukainen)		
KALA		
Kalaruoat ja kalavalmisteet (esim. kalakeitto, paistettu kala, tonnikala)		
MAKEISET JA NAPOSTELTAVAT		
Suklaa ja makeiset		
Perunalastut, juustonaksut ja popcorn		
JUOMAT		
Täysmehu (esim. appelsiinituoremehu)		
Sokeripitoinen limsa, mehu ja energiajuoma		
Sokeriton limsa, mehu ja energiajuoma (light)		

KIITOS VASTAUKSISTASI!