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LIFESTYLE HABITS AND NOVEL MEANS FOR DIETARY SCREENING AND HEALTH PROMOTION IN PREGNANT WOMEN AND CHILDREN

Ella Koivuniemi

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ABSTRACT

Lifestyle habits, including diet and physical activity, that deviate from the recommendations during pregnancy and early childhood may eventually increase the risk for obesity and other lifestyle-related diseases in both the mother and the child. High prevalence of obesity among pregnant women and children in Finland suggest that novel means to support health-promoting lifestyle habits among these target groups are needed. Thus, the aim was to assess lifestyle habits of pregnant women and children with reference to the national recommendations. Another aim was to study the effects of a health app for improving lifestyle habits during pregnancy and to develop a short method for the assessment of diet quality in children for dietary screening and health promotion purposes.

Weight, diet quality and physical activity during early and late pregnancy as well as the efficacy of the health app on improving these lifestyle habits were investigated in 1038 Finnish women (study I). Further, food supplement use during pregnancy was studied in 1804 women from Finland, Italy, Poland and the United Kingdom (study II). Diet quality was assessed with a validated index in 766 preschool-aged children (study III) and diet with food diary and food frequency questionnaire in 266 elementary school-aged children (study IV). Moreover, a tool for assessing diet quality in elementary school-aged children was developed (study IV).

The results indicated that the diet quality and physical activity levels were suboptimal in majority of the pregnant women. Most of the women consumed vitamin D and folic acid supplements during pregnancy, but adherence to the recommended doses was low. No benefits on the use of the health app were seen in diet quality and weight gain. However, physical activity level among app users decreased less likely compared with app non-users over the pregnancy course, indicating that the benefits of the app use may arise from maintenance of physical activity. The results also showed that diet quality was suboptimal in most of the preschool and elementary school-aged children; especially the consumption of vegetables, fruits and berries was low. The developed stand-alone index depicted diet quality in elementary school-aged children as defined in the dietary recommendations. Thus, it may be used as a valid tool in e.g. dietary screening.

KEYWORDS: pregnancy, childhood, diet quality, food supplement, physical activity, gestational weight gain, health app, diet quality index, dietary screening

TURUN YLIOPISTO
Lääketieteellinen tiedekunta
Biolääketieteen laitos
Ravitsemus, ruoka ja terveys
ELLA KOIVUNIEMI: Raskaana olevien naisten ja lasten elintavat sekä uudet menetelmät seulonnan ja terveyden edistämisen tueksi
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TIIVISTELMÄ

Suosituksista poikkeavat elintavat eli ravitsemuslaadultaan heikko ravinto ja riittämätön liikunta raskausaikana ja lapsuudessa voivat ajan myötä kohottaa lihavuuden ja muiden elintapasairauksien riskiä sekä äidillä että lapsella. Lihavuuden suuri esiintyvyys suomalaisilla raskaana olevilla naisilla ja lapsilla osoittaa, että uusia keinoja tarvitaan terveyttä edistävien elintapojen tukemiseen näissä kohderyhmissä. Tämän väitöskirjan tavoitteena oli selvittää raskaana olevien naisten ja lasten elintapoja suhteessa suosituksiin. Lisäksi tavoitteena oli tutkia terveyssovelluksen hyötyjä raskausajan elintapojen parantamiseksi sekä kehittää lyhytmenetelmä lasten ruokavalion laadun selvittämiseksi käytettäväksi seulonnan ja terveyden edistämisen tueksi.

Tutkimuksessa selvitettiin suomalaisten raskaana olevien naisten (n=1038) paino, ruokavalion laatu ja fyysinen aktiivisuus sekä terveyssovelluksen hyödyt näiden elintapatekijöiden parantamisessa (tutkimus I). Lisäksi kysyttiin ravintolisien käyttö raskaana olevilta naisilta (n=1804), jotka asuivat Suomessa, Italiassa, Puolassa tai Iso-Britanniassa (tutkimus II). Alle kouluikäisten lasten (n=766) ruokavalion laatu selvitettiin validoidulla indeksillä (tutkimus III) ja alakouluikäisten lasten (n=266) ravintotekijät ruokapäiväkirjan ja frekvenssikyselyn avulla (tutkimus IV). Lisäksi kehitettiin työväline alakouluikäisten lasten ruokavalion laadun selvittämiseen (tutkimus IV).

Suurella osalla raskaana olevista naisista ruokavalion laatu oli suosituksia heikompaa ja fyysinen aktiivisuus suositeltua vähäisempää. Suurin osa naisista käytti D-vitamiini- ja foolihappolisää raskauden aikana, mutta eivät suositusten mukaisin annoksin. Terveyssovelluksen käyttö ei vaikuttanut ruokavalion laatuun eikä painoon. Sovellus saattaa kuitenkin motivoida raskaana olevia naisia fyysisen aktiivisuuden ylläpitämiseen raskauden edetessä. Tulokset osoittivat myös, että ruokavalion laatu oli heikko tai kohtalainen suurella osalla alle kouluikäisistä ja alakouluikäisistä lapsista; erityisesti kasvisten, hedelmien ja marjojen käyttö oli vähäistä. Tutkimuksessa kehitetty lyhytmenetelmä kuvaa alakouluikäisten lasten ruokavalion laatua suhteessa suosituksiin. Sitä voidaan käyttää esimerkiksi validina seulontatyökaluna.

AVAINSANAT: raskaus, lapsuus, ruokavalion laatu, ravintolisä, painonnousu, fyysinen aktiivisuus, terveyssovellus, ruokavalion laatuindeksi, seulonta

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Main abbreviations

ACARFS	the Australian Child and Adolescent Recommended Food Score
ARFS	the Australian Recommended Food Score
BMI	Body mass index
CI	Confidence interval
CIDQ	the Children's Index of Diet Quality
DQI	the Diet Quality Index
DQS	the Diet Quality Score
ES-CIDQ	the Elementary-school aged Children's Index of Diet Quality
E%	Percent of energy intake
FCHEI	the Finnish Children Healthy Eating Index
FFQ	Food frequency questionnaire
GDM	Gestational diabetes mellitus
GWG	Gestational weight gain
HEI	the Healthy Eating Index
IDQ	the Index of Diet Quality
IOM	Institute of Medicine
KIDMED	the Mediterranean Diet Quality Index for children and adolescents
LTPA	Leisure time physical activity
MET	Metabolic equivalent of task
MJ	Megajoule
MD	Mediterranean diet
MDS	Mediterranean Diet Score
OR	Odds ratio
ROC	Receiver operating characteristic
SD	Standard deviation
SFA	Saturated fatty acids
UK	the United Kingdom
US	the United States
WHO	the World Health Organization

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Koivuniemi E, Raats MM, Ollila H, Löyttyniemi E, Laitinen K. Characterising the use, users and effects of a health app supporting lifestyle changes in pregnant women. *British Journal of Nutrition*, 2023; 3: 433–445.

II Koivuniemi E, Hart K, Mazanowska N, Ruggeri S, Egan B, Censi L, Roccaldo R, Mattila L, Buonocore P, Löyttyniemi E, Raats MM, Wielgos M, Laitinen K. Food Supplement Use Differs from the Recommendations in Pregnant Women: A Multinational Survey. *Nutrients*, 2022; 14: 2909.

III Koivuniemi E, Gustafsson J, Mäkelä I, Koivisto VJ, Vahlberg T, Schwab U, Niinikoski H, Laitinen K. Parental and Child Factors Associated With 2- to 6-Year-Old Children's Diet Quality in Finland. *Journal of the Academy of Nutrition and Dietetics*, 2022; 1: 129–138.e4.

IV Koivuniemi E, Nuutinen O, Riskumäki M, Vahlberg T, Laitinen K. Development of a stand-alone index for the assessment of diet quality in elementary school-aged children. *Public Health Nutrition*, 2021; 17: 5629–5640.

1 Introduction

Gestation and early childhood are critical phases of life for defining the health of both mother and child. Health-promoting maternal lifestyle habits, i.e. dietary habits and physical activity in accordance with the recommendations, support e.g. the gestational weight control in the mother as well as the healthy growth and development of the foetus [1,2]. However, the main challenges in the diets of Finnish adults are low consumption of fibre and vegetables, fruits and berries and high consumption of saturated fat and salt [3]. For example, only 22% of Finnish women consumed 500 grams of vegetables, fruits and/or berries as recommended in 2017 [3]. Similar challenges in diet have been found in Finnish children: low consumption of vegetables, fruits, berries, fish and fibre as well as high consumption of saturated fat and sucrose [4–8]. A study among 6−8-year-old children reported that only 5% of the children consumed vegetables, fruits and berries five portions a day as recommended [5].

Alongside the poor diet, the amount of physical activity should be improved in all age groups in Finland [9,10]. It has been estimated that only 11−24% of the adult population meet the overall health-enhancing physical activity recommendations [9,11,12]. Among children, the prevalence of meeting physical activity recommendations has slightly increased in the recent decades; nevertheless, only two out of three preschool-aged and half of elementary school-aged children meet the physical activity recommendations [10].

In addition to excess energy intake, poor diet quality, i.e. food choices not in accordance with dietary recommendations, and sedentary behaviour may in time lead to the development of obesity (Figure 1), which is further linked to increased risk of mortality and several non-communicable diseases such as cardiovascular disease, type 2 diabetes and metabolic syndrome [13]. Moreover, maternal lifestyle habits and obesity before and during pregnancy have a great impact on both short and long-term health of the child through foetal programming; the metabolism of the foetus adapts to the maternal environment to thrive which may increase the risks of lifestyle-related diseases also in the child later in life [14,15]. To date, almost half of Finnish women have overweight or obesity [16]. Increasing prevalence of obesity has also increased e.g. the prevalence of gestational diabetes mellitus (GDM) that has doubled in a decade; in 2019, every fifth Finnish women was affected [17]. GDM may increase the risk for children's high birth weight and macrosomia, which in turn may lead to difficulties in delivery [18]. GDM has also been linked with e.g. children's elevated risk of deviant glucose metabolism and overweightness or obesity extending into adulthood [19,20]. Alarmingly, the prevalence of overweight and obesity has increased among Finnish children. In 2020, 16% and 27% of preschool-aged girls and boys, respectively, and 19% and 30% of elementary school-aged girls and boys, respectively, were affected by overweight or obesity [21].

As the unhealthy lifestyle habits strain both the individual health and health care system, prevention of obesity and other lifestyle-related diseases should be started already from the early life, i.e. pregnancy and childhood. However, lifestyle changes are difficult to implement as considerable motivation and commitment are demanded. Mother's poor understanding of health-promoting lifestyle habits as well as lack of time and support are common barriers for adopting a health-promoting lifestyle during pregnancy [22]. In Finland, the health of pregnant women and the growth and development of children are followed regularly, both mothers and the foetus in the maternity clinic, and later children in the child health clinics and within the school health care system. During these free-of-charge health clinic visits, registered nurses e.g. conduct physical examinations, monitor the child's growth and wellbeing and provide health and dietary counselling for the children and families [23]. The high prevalence of overweight and obesity in all age groups in Finland suggests that despite the comprehensive health clinic system, supporting lifestyle changes in health care may be inadequate due to e.g. lack of resources. Valid and easy-to-use methods are needed for the assessment of lifestyle habits in mother and child as well as to support health-promoting lifestyle habits in order to prevent obesity and other lifestyle-related diseases. Previous scientific evidence suggests that health apps, e.g. health-promoting mobile applications which include health information and/or tools for self-monitoring, may help in supporting lifestyle changes during pregnancy [24–26], and thus preventing health problems in mother and child in the long term. Furthermore, child dietary screening and subsequent counselling could be enhanced with valid diet quality indices that may be used in identifying those children most in need of the counselling.

In this thesis, lifestyle habits, namely diet (the focus being on diet quality, food consumption and food supplement use), physical activity and gestational weight gain, were assessed in pregnant women as well as diet (diet quality, food consumption and dietary patterns) in preschool-aged and elementary school-aged children to understand the current situation in relation to the national recommendations. To identify novel means for the benefit of dietary screening and health promotion, the potential of a health app as a tool for health promotion was investigated by assessing the effects of health app use and additional health information provided via the app on lifestyle habits in pregnant women. Furthermore, a short method for the assessment of diet quality in Finnish elementary school-aged children was developed to serve as a valid tool for screening and dietary counselling in school health care.

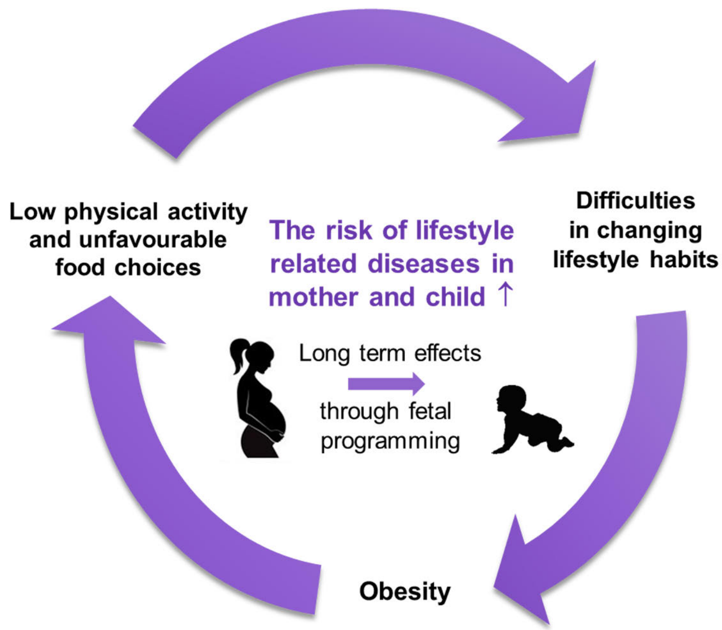

Figure 1. Unfavourable lifestyle habits of the mother and difficulties in conducting lifestyle changes may in time lead to obesity, resulting in a vicious cycle that further leads to increased risk of other lifestyle-related diseases both in the mother and the child in long-term.

2 Review of the Literature

2.1 Lifestyle habits in Finnish pregnant women

2.1.1 Diet during pregnancy

2.1.1.1 Health-promoting diet and dietary assessment methods

A diet of high quality during pregnancy is known to be of importance for the health of the both the mother and the foetus. A high-quality diet consists of balanced, healthy food choices that comply with the dietary recommendations [27]. It is characterised by high consumption of vegetables, fruits and berries, fish, dietary fibre and unsaturated fats, enough of vitamins and minerals as well as low consumption of saturated fats and refined sugars. A high-quality diet ensures that the individual consumes a nutrient-rich, health-promoting diet. In Finland, the national dietary recommendations for pregnant women are issued by the National Nutrition Council [28] and the National Institute for Health and Welfare [29]. The recommendations take into account the increased need of energy and nutrients during pregnancy and serve as a reference for the assessment of a health-promoting diet. Traditionally the intakes of foods and nutrients have been measured with food diaries, dietary recalls or food frequency questionnaires. As dietary recommendations highlight the overall quality of diet, it is reasonable to measure the diet with an instrument that defines the diet as a whole, not only separate foods or nutrients. Overall healthiness of the diet can be described by using e.g. diet quality indices and dietary patterns.

Diet quality indices can be used to assess the overall quality of diet based on scoring food patterns with reference to the dietary recommendations [27]. Further, the scoring can be based e.g. on the diversity of healthy and unhealthy food choices [27]. The indices can be constructed in several ways: to assess either specific foods, nutrients or the combination of foods and nutrients [30]. Also, the scoring methods and cut-off points differ across the indices as they can be based e.g. on statistical analyses or the healthy intake level as set in the dietary recommendations. In order to study the diet in more detail, the consumption of diet quality components, i.e.

separate food items or ‘the health indicator foods’, can be assessed. Consumption of vegetables, fruits and berries, fish and low-fat dairy, can be used as simple indicators of health-promoting diet as, based on scientific evidence, they are central food groups linked with health; thus, their consumption is promoted in the dietary recommendations.

Alongside the assessment of diet quality and food consumption, dietary patterns can be identified from food groups to evaluate the diet in a comprehensive way and taking account the complexity of diet. Dietary patterns can be used to depict the dietary characteristics in a population level. However, dietary pattern analysis has also challenges including its nature as a data driven, explorative approach that requires several decisions during the data analysis process which further diminishes its reproducibility as such in another population of pregnant women. Also, the generalisability of the results may be low as the method is based on observations on one study population.

2.1.1.2 Diet

The existing studies on diet quality, as measured with diet quality indices, during pregnancy in Finland are based on three pregnancy cohorts (FOPP study, RADIEL study and STEPS study) in which the data collection has been conducted 5−15 years ago in certain regions of Finland. In the studies, diet quality has been assessed with two different validated diet quality indices: the Index of Diet Quality (IDQ) [31] and Healthy Food Intake Index (HFII) [32]. In both indices, higher scores indicate a better adherence to national dietary recommendations [28,33] and they assess the consumption of same dietary components, including vegetables, fruits and berries, fish, low-fat dairy and vegetable oil-based spread, defined important for a high-quality diet in the dietary recommendations. However, the indices have some differences in how they can be used and how the results can be interpreted. The IDQ was developed to assess the adherence to Finnish dietary recommendations and the development process was based on statistical analyses with a three-day food diary as a reference method [31]. Further, the scoring of IDQ was based on statistical analyses and the degree of fulfilling the dietary recommendations [31]. The HFII was compiled to assess the adherence to Nordic Nutrition Recommendations and the index questions were selected from a semi-quantitative FFQ to reflect the recommendations [32]. The scoring of the HFII was based on the degree of fulfilling the dietary recommendations, medians and tertiles of the index components or consensus panel decisions on the scores [32]. The IDQ is a stand-alone index that can be used as it is, while HFII is calculated based on data collected with a supportive method, a food frequency questionnaire. Furthermore, the IDQ was developed to depict the diet quality also in a categorised form, e.g. having either ‘good’ or ‘poor’ diet quality (scores ≥10 indicating good diet quality based on the original validation study [31], in which higher adherence to criteria chosen from the dietary recommendations was considered as good diet quality based on the selected cut-off value), which enables its use for example in screening purposes. This kind of approach is not possible with HFII.

Findings of the previous studies on diet quality in Finnish pregnant women are shown in Table 1; in case of intervention studies, only the results of the control group have been presented, when possible, in order to provide an overview of diet quality representing the more general population of pregnant women. The diet quality in Finnish pregnant women is relatively good, although still in a suboptimal level in reference to dietary recommendations [29]. Findings from the FOPP and STEPS studies on diet quality, assessed with IDQ, showed that the median diet quality scores in early and late pregnancy were slightly under the cut-off value of 10 points for good diet quality (Table 1) [34–36]. In the FOPP study including women with overweight or obesity, it was reported that half of the women had good diet quality in early pregnancy, but the proportion increased as pregnancy proceeded, being 58% in late pregnancy [36]. Further, another study from the FOPP study data showed that the proportion of women with good diet quality was higher in those women who did not develop GDM during pregnancy [35]. Interestingly, findings from the STEPS study indicated that in mid-pregnancy women with overweight had better diet quality scores than women with normal weight [34]; this might be due to e.g. dietary counselling received from maternal health clinics. Results from the RADIEL study are aligned with the aforementioned studies, although using a different method, in that the reported diet quality scores were around 10 points, e.g. slightly over half of the highest possible score of 17 points [32,37]. Moreover, the diet quality scores somewhat improved in late pregnancy compared to early pregnancy in the control group [37].

Regarding the food consumption (Table 1), only one of four pregnant women consumed vegetables, fruits and berries five portions a day as recommended in the national dietary recommendations; however, majority of the women consumed vegetables, fruits and berries on a daily basis [38]. Moreover, less than half of the pregnant women consumed skimmed milk and soft margarine with over 60% of fat on a daily basis and fish on a weekly basis as recommended [38]. Another study including pregnant women with GDM risk factors reported similar findings regarding spread: only half of the women in early pregnancy and a third of the women in late pregnancy consumed vegetable oil-based spread on bread [39]. Furthermore, the NELLI study reported that women consumed fish, on average, 1.4 and 1.5 times a week in mid-pregnancy and late pregnancy [40], respectively, while the recommended consumption of fish is two to three times a week during pregnancy. Regarding the eating frequency, which is also an important part of health-promoting diet, it was shown that around two thirds of pregnant women had a recommended eating frequency (4–6 meals/day) in early pregnancy [35]. The results indicate that although most women consume regularly the components of good diet quality, the consumption of e.g. vegetables, fruits and berries, fish and vegetable oil-based fat could still be improved in reference to dietary recommendations.

In Finland, three studies have identified dietary patterns in a pregnant women population. Although these studies do not report the proportions of women adhering to the different dietary patterns, the results may help in understanding e.g. the dietary challenges in Finnish women. From a retrospective data collected over 20 years ago, altogether seven dietary patterns were identified among pregnant women (n=3730) [41]. The patterns were named as follows: 'Healthy' (characterized by higher consumption of e.g. vegetables, fruits and berries, fish, poultry and eggs), 'Fast foods' (higher consumption of e.g. fast foods, snacks, sweets and chocolate and soft drinks), 'Traditional bread' (higher consumption of e.g. pastries, whole-grain bread, high-fat cheese and tea), 'Traditional meat' (higher consumption of e.g. meat dishes, processed and organ meat, sausage and potatoes), 'Low-fat foods' (higher consumption of e.g. spread with fat content of 40–60%, low-fat cheese, low-fat dairy products and lower consumption of butter and high-fat dairy products), 'Coffee' (higher consumption of e.g. coffee and coffee milk) and 'Alcohol and butter' (higher consumption of beer, wine, liquor and butter) [41]. More recently, three distinct dietary patterns were identified in a population of pregnant women with obesity or history with GDM (n=433): 'Fat factor' characterized by a higher consumption of cooking fat, spread, low-fat cheese and low-fat milk; 'Healthy foods' characterized by higher consumption of high-fibre grains, vegetables, fruits, berries and fish; and finally 'Unhealthy foods' characterized by a higher consumption of snacks, sugar-sweetened beverages and fast food [32]. Furthermore, in another study population of pregnant women with overweight or obesity (n=351), two patterns were identified: 'Healthier pattern' characterized by a high consumption of e.g. vegetables, fruits and berries, rye bread, fish, margarine and oils as well as 'Unhealthier pattern' characterised by higher consumption of e.g. multigrain and wheat bread, dairy desserts, sweet and savoury pastries, sweet and savoury snacks, nuts and seeds [35].

Nutrient and food intakes have also been assessed in Finnish pregnant women, but as this dissertation research has been delimited in studying the overall quality aspect of diet in pregnancy, rather than the specific nutrient and food intakes, those results are not reported here. More timely information of a nationwide population of pregnant women is needed on the diet quality in order to evaluate whether the diet quality is in an adequate level as compared to the national dietary recommendations during pregnancy.

Table 1. Diet quality and food consumption in Finnish pregnant women.

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
Mäkelä et al. 2013 [34]	STEPS birth cohort study (observational follow-up study)	149 women with normal weight or overweight	Gestational weeks of 26-28	IDQ; score range 0-18 points, good diet quality >10 points	IDQ scores - normal weight - overweight	 9.5 ± 3.3 10.6 ± 2.0
Pellonperä et al. 2019 [36]	FOPP intervention study (fish oil & probiotics)	110 women with overweight or obesity	Gestational weeks of 13.5 and 35.3	3-day food diary and IDQ; score range 0-18 points, good diet quality >10 points	IDQ scores - Early pregnancy - Late pregnancy Good diet quality, % - Early pregnancy - Late pregnancy	 9.8 ± 2.2 9.8 ± 2.1 50 58
Pajunen et al. 2022 [35]		351 women with overweight or obesity GDM+ group: 81 women who developed GDM after the baseline visit GDM- group: 270 women who did not develop GDM	Gestational weeks: GDM+ 14.2±2.0 GDM- 13.8±2.1	3-day food diary and IDQ	IDQ scores - GDM+ - GDM- Good diet quality, % - GDM+ - GMD- Frequency of consuming meals consisting of any food/beverage - GDM+ - GDM- Having a recommended eating frequency (4–6 meals/day, %) - GDM+ - GDM−	 9.4 ± 2.1 9.6 ± 2.1 42.5 50.2 5.7 ± 1.3 5.8 ± 1.3 69 73

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Review of the Literature

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
Meinilä et al. 2016* [32]	RADIEL intervention study (lifestyle counselling)	443 women with obesity or history with GDM	Gestational weeks of 12.5 ± 1.9	HFII calculated from FFQ; scores 0−17	HFII scores	10.2 ± 2.8
Rönö et al. 2018** [37]		243 women with obesity or history with GDM (only control group included)	Gestational weeks of 13 and 35	HFII calculated from FFQ	HFII scores Change in HFII scores from early to late pregnancy	9.8 ± 2.6*** ↑ 0.4 points, (0.0, 0.8)
Arkkola et al. 2006 [38]	DIPP birth cohort study (observational follow-up study)	797 women with children with type 1 diabetes risk gene	8th month of gestation, assessed retrospectively after delivery	181-item FFQ	**Daily use, %** Skimmed milk Rye bread Vegetables Fruits & berries Vegetables, fruits & berries ≥5 portions/day Soft margarine, >60% fat Soft margarine, ≤60% fat Sugary soft drinks Sweets **Weekly use, %** Fish	 39 76 88 76 24 43 22 4 18 48
Kinnunen et al. 2014 [40]	NELLI intervention study (lifestyle counselling)	180 women with at least one GDM risk factor (only control group included)	Gestational weeks of 26–28 and 36–37; diet during the previous month	181-item FFQ	**Mid-pregnancy** Use of high fibre bread, % of all bread Fat-free or low-fat milk, % of all milk Low-fat cheese, % of all cheese Vegetable fats, % of all fats Frequency of eating fish per week	 61 ± 25 62 ± 36 30 ± 35 54 ± 23 1.4 ± 1.0

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
					Late pregnancy	
					Use of high fibre bread, % of all bread	60 ± 24
					Fat-free or low-fat milk, % of all milk	67 ± 34
					Low-fat cheese, % of all cheese	38 ± 40
					Vegetable fats, % of all fats	52 ± 25
					Frequency of eating fish per week	1.5 ± 1.1
Korpi-Hyövälti et al. 2012 [39]	Intervention study (dietary counselling)	27 women with GDM risk factors (only control group included)	Gestational weeks of 8-12 and 36-40	4-day food diary	**Early pregnancy, %**	
					Vegetable oil spread	54
					Dairy fat-based spread	29
					No spread	17
					Late pregnancy, %	
					Vegetable oil spread	32
					Dairy fat-based spread	42
					No spread	26

Data presented as % of participants, mean ± standard deviation or mean difference (95% confidence interval lower bound, upper bound). In intervention studies, only the results of control group included in the table when possible and necessary. * Two studies reported similar results for the HFII scores of the same study data with a smaller number of participants [42,43]. ** One study reported similar results of the same study data with a smaller number of participants [44]. *** The mean scores differ from those reported in [32] as they reported the mean scores from the intervention and control group together, whereas here, only the results from the control group are shown. FFQ, food frequency questionnaire; GDM, gestational diabetes mellitus; HFII, the Healthy Food Intake Index; IDQ, the Index of Diet Quality. ↑ denotes increase.

2.1.1.3 Food supplement use

The need for energy and nutrients increases during pregnancy to support the growth and development of the foetus as well as the increased growth of placenta and other tissue in mother [45,46]. To guarantee sufficient intake of vitamins and minerals, additional recommendations for the consumption of particular micronutrients as food supplements have been made in most countries. In Finland, vitamin D and folic acid supplements are recommended to be used during pregnancy [28]. In addition, the use of some vitamin and mineral supplements, such as calcium, iron, and iodine supplements are recommended to those pregnant women with deficient intakes from their diet [28]. It is of note that excessive use of food supplements at higher than recommended doses might also induce adverse effects on both the mother and the foetus, e.g. high doses of vitamin A might have teratogenic effects [47], whereas high doses of iron may increase the risk of GDM [48,49]. Therefore, assessing the use of food supplements and adherence to the supplements recommendations during pregnancy is essential to ensure appropriate use.

In Finland, several studies have reported food supplement use during pregnancy (Table 2). However, the existing information is mostly gathered in cohort studies or clinical trials as secondary outcomes and it mainly concentrates on the overall prevalence of using any supplements or particular supplements, such as vitamin D. Less is known about the daily intakes of nutrients from food supplements and whether the doses are in line with national recommendations for pregnant women. The reporting styles also vary between the studies; some studies report the intake of vitamins and minerals from multivitamin and single supplements separately [35,50], while in other studies the intake from multivitamins has not been reported separately [39,51–53].

Previous findings from Finnish studies indicate that the use of any food supplements during pregnancy is common (77−96% of women) [35,39,50–53]. One study including pregnant women with GDM risk factors also reported the prevalence of any supplement use of only 33%, but the number of participants was small (n=27) and the food supplement use was not systemically reported during the data collection [39]. Two studies reported that approximately two thirds of the women used multivitamin supplements [35,50]. In the Fish Oil and Probiotics in Pregnancy (FOPP) study with women with overweight and obesity women, most used prenatal multivitamin supplements and only 5% used general multivitamin products [35]. In Finland, prenatal multivitamin products are typically formulated to consider the nutritional needs of pregnancy: they contain several vitamins and minerals including vitamin D, folic acid and iron, but not vitamin A.

The reported prevalence of using vitamin D supplements (24−89%) varied greatly between the studies [35,50–53]. However, the interpretation of the results is difficult as some studies reported the consumption both from single or multivitamin supplements and others only from single supplements, likely also reflecting the products available in the markets at the time. The FOPP study also reported separately the prevalence of using a combination supplement with vitamin D and calcium (6.6%) [35]. Only the Type 1 Diabetes Prediction and Prevention Study (DIPP) reported the daily intake of vitamin D from the supplements, the intake being 1.3 µg [51]. Two other studies from the same DIPP study data reported the daily intake of vitamin D between 1.2 and 3.7 µg [38,54]. Overall, the intake of vitamin D from supplements was notably lower than the recommended daily intake of 10 µg during pregnancy.

The frequency of using folic acid supplements was even lower than that of vitamin D supplements; the prevalence varied between 14 and 64% [35,51,53]. The daily intake of folic acid supplements was 57 µg (n=3439) [51] and 111 µg (n=679) [38] in the DIPP study participants, and considerably below the recommended daily intake of 400 µg from supplements during pregnancy [29]. It should be noted that the folic acid supplement is recommended to be used until 12th pregnancy week and some of the participants have possibly been further in their pregnancies at the time of the study. In addition, the recommendation for the use of folic acid supplements was expanded to include all pregnant women in 2016, which may explain the low consumption in some previous studies in which the data was gathered prior to the current recommendation.

As for the use of iron supplements, the prevalence was reported to be 3−73%. The lowest prevalence was reported in the FOPP study [35], but it is of note that the prevalence was reported from single supplements only and did not consider if the participants used multivitamin supplements that may also contain iron. The DIPP study reported the mean daily intake of supplemental iron being 27 mg [51], whereas another study from the same DIPP data reported a daily intake of 59 mg [38]. The difference between the studies may be explained by e.g. a different number of subjects (n=3439 and n=679, respectively) and as the subjects with multiple pregnancies were left out of the analyses in the larger study [38,51]. The reported intakes are fairly high as the daily safe upper intake limit of iron is 25 mg for adults [28], except for when treating anaemia. In Finland, indeed, supplemental iron (50 mg/day) is recommended to be used only for pregnant women with low haemoglobin [29]. However, the nutrients from the supplement products are not fully absorbed by the body [55].

According to the previous studies, the proportion of pregnant women using calcium supplements was 17−47% [50,51,53] and the mean daily intake from supplements, which was reported only in one study, was 68 mg [51]. Again, another study from the same data reported the daily intake of 359 mg of calcium supplements with a smaller number of subjects [38]. Additionally, two studies reported the prevalence of using iodine supplements (0−45%), but neither reported the daily intake [35,53]. In Finland, both calcium (500−1000 mg) and iodine (150 µg) are recommended to be used as supplements for pregnant women with very low intake from diet [28].

Interestingly, one study reported that even one third of the participants used vitamin A supplements [38], although vitamin A is not recommended to be used during pregnancy due to its potential teratogenic effects [47]. This is likely due to women using general multivitamin supplements that contain vitamin A in contrast to prenatal multivitamins. Two women also took vitamin A from a single supplement [38]. Two other studies reported a prevalence of 3−6% for using vitamin A supplement [51,53]. Furthermore, the reported mean daily intake of vitamin A supplements varied between 17 and 172 µg; both results are from the DIPP study [38,51].

Based on the previous studies, the prevalence of users and intakes of vitamin D and folic acid supplements seem to be lower than recommended. However, it needs to be taken into consideration that the reporting of the results and methods for data collection has varied greatly between the studies and e.g. the recommendation for folic acid supplementation was changed in 2016 to consider all pregnant women. Furthermore, there are no detailed information available on the consumption of all vitamins and minerals as food supplements and most of the results are based on data gathered over 10 years ago. Thus, there is a demand for more detailed information on the timely use of food supplements, especially on the exact daily intakes of food supplements, during pregnancy.

Table 2. Food supplement consumption and intake in Finnish pregnant women.

REFERENCE	**Piirainen et al. 2006** [50]	**Salmenhaara et al. 2010** [51]	**Korpi-Hyövälti et al. 2012** [39]	**Aronsson et al. 2013** [52]	**Meinilä et al. 2015** [53]	**Pajunen et al. 2022** [35]
Study design	Intervention study (dietary counselling + probiotics)	DIPP birth cohort study* (observational follow-up study)	Intervention study (dietary counselling)	TEDDY birth cohort study (observational follow-up study)	RADIEL intervention study (lifestyle counselling)	FOPP intervention study (fish oil + probiotics)
Participants	209 healthy and atopic women	3439 women with children with type 1 diabetes risk gene; women with GDM (n=174) excluded from the table	27 women with GDM risk factors (control group)	1622 women with children with type 1 diabetes risk gene	234 women with obesity or history with GDM	351 women with overweight or obesity
Stage of pregnancy	Whole pregnancy, inquired at mean gestational weeks of 14, 24 & 34	Whole pregnancy time; inquired at 1-3 months postpartum	Early pregnancy, gestational weeks of 8-12	Whole pregnancy time, inquired at 3-4 months postpartum	<20 weeks of gestation	Early pregnancy
Method to assess supplement use	Interview	Validated FFQ with open-ended questions on supplement use	4-day food diary; supplement use not reported systematically	Questionnaire	A separate question about supplement use in a 3-day food diary	A separate question about supplement use in a 3-day food diary
Any supplement						
Consumption, %	96	77.4	33	87.1	77	94.3
Multivitamin and multimineral						
Consumption, %	68	-	-	-	-	71.2
Vitamin A						
Consumption, %	-	6.1	-	-	3	-
Intake, µg	-	16.9 ± 103.0	-	-	-	-
Folic acid						
Consumption, %	-	36.5	-	-	64	13.7
Intake, µg	-	57.1 ± 98.4	-	-	-	-

REFERENCE	**Piirainen et al. 2006** [50]	**Salmenhaara et al. 2010** [51]	**Korpi-Hyövälti et al. 2012** [39]	**Aronsson et al. 2013** [52]	**Meinilä et al. 2015** [53]	**Pajunen et al. 2022** [35]
Vitamin C						
Consumption, %	-	31.3	-	-	55	4.3
Intake, mg	-	23.2 ± 83.3	-	-	-	-
Vitamin D						
Consumption, %	89, 87 in winter	30.3	-	71.4	72	23.6
Intake, µg	-	1.30 ± 2.59	-	-	-	-
Vitamin E						
Consumption, %	-	34.9	-	-	57	-
Intake, mg	-	1.13 ± 5.04	-	-	-	-
Calcium						
Consumption, %	47	17.3	-	-	19	-
Intake, mg	-	68.2 ± 177.2	-	-	-	-
Iron						
Consumption, %	73	69.4	-	-	41	2.8
Intake, mg	-	27.0 ± 33.3	-	-	-	-
Iodine						
Consumption, %	-	-	-	-	45	0

Data presented as % of participants or mean ± standard deviation. In intervention studies, only the results of control group included in the table when possible. *Two other studies reported similar results of the same DIPP study population with a smaller number of participants or less versatile data [38,54]. FFQ, food frequency questionnaire; GDM, gestational diabetes mellitus.

2.1.2 Physical activity during pregnancy

Alongside a balanced diet, physical activity during pregnancy is beneficial for the health of both the mother and the foetus. For example, maintenance of physical activity during pregnancy is related to a lower risk of pregnancy complications, such as GDM, gestational hypertension and pre-eclampsia [56,57]. In Finland, it is recommended to perform at least 150 minutes of moderate-intensity leisure-time physical activity (LTPA) per week as well as resistance training and balance activities at least twice per week during pregnancy [58].

Findings from the studies assessing physical activity in Finnish pregnant women are presented in Table 3; regarding intervention studies, only the results of the control group have been presented when possible, in order to provide an overview of the data representing the general population of pregnant women. It is also noteworthy that the findings reported here are mostly based on studies in which the data has been collected from 10 to 20 years ago. The previous findings indicate that only 14−30% of women complied with the physical activity recommendation of performing at least 150 minutes of moderate-intensity LTPA per week during the second and the third trimester [37,59,60]. For example, 23% of pregnant women met the recommendation during the second trimester [44] and only 14% of the women met the recommendation during the third trimester [37]. In this RADIEL study, the median duration of LTPA was only 60 minutes per week, which is notably lower than the recommended 150 minutes [32,37,44]. Furthermore, it was reported in several studies that the physical activity levels decreased between the last two trimesters [36,37,50,61]. Over a third of the participants were found to reduce their physical activity during pregnancy [61], and another study showed that in the first trimester, the women had a mean of 2.2 weekly episodes of aerobic physical activity exceeding 30 minutes per time, but by the third trimester it had decreased to only one weekly episode of physical activity [50]. The findings are reasonable as e.g. the intensity of pelvic girdle pain often increases as the pregnancy proceeds [62]. Additionally, in a longitudinal cohort study with smartwatch technology (n=38), it was reported that although the participants self-evaluated that their weekly physical activity did not change, their step counts decreased and daily inactive time increased as the pregnancy proceeded, as measured by the smartwatch [63]. This may support the suggestion that mothers own false perceptions of already being active may also diminish the physical activity during pregnancy [64].

In conclusion, a small proportion of Finnish pregnant women comply with the physical activity recommendations and the physical activity decreases during pregnancy although maintaining physical activity as pregnancy proceeds could be beneficial for the mother and the child. Thus, new means for improving the physical activity levels during pregnancy are needed.

Table 3. Physical activity in Finnish pregnant women.

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
Aittasalo et al. 2012 [59]	NELLI intervention study (lifestyle counselling)	180 women with at least one GDM risk factor (only control group included)	Gestational weeks of 26-28 and 36-37	LTPA questionnaire modified from the IPAQ	**Mid-pregnancy**	
					Total LTPA	
					- days/wk	6.7 ± 3.6
					- min/wk	309 ± 292
					Moderate-to-vigorous LTPA	
					- days/wk	3.1 ± 2.6
					- min/wk	132 ± 144
					Light LTPA	
					- days/wk	3.6 ± 2.3
					- min/wk	177 ± 213
					Meeting PA recommendations, %	30
					Late pregnancy	
					Total LTPA	
					- days/wk	6.5 ± 3.5
					- min/wk	310 ± 289
					Moderate-to-vigorous LTPA	
					- days/wk	2.4 ± 2.5
					- min/wk	101 ± 147
					Light LTPA	
					- days/wk	4.1 ± 2.3
					- min/wk	207 ± 201
					Meeting PA recommendations, %	23

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
Kolu et al. 2014 [60]	NELLI intervention study (lifestyle counselling)	338 women with at least one GDM risk factor; no differences in the physical activity measures between intervention groups (both groups included here)	Gestational weeks of 36–37	LTPA during a typical week of the previous three weeks inquired with a questionnaire	Women with ≥150 / <150 min/wk of moderate-intensity LTPA, n Meeting PA recommendations, % Performing ≥150 min/wk of moderate-intensity aerobic PA, %	80 / 258 24 17
Leppänen et al. 2014 [61]		399 pregnant women with at least one GDM risk factor 219 women in the intervention and 180 in the control group; no differences in the physical activity between the groups	Gestational weeks of 26-28 and 36-37	LTPA questionnaire modified from the IPAQ	Met PA recommendations at the end but not at the beginning of the pregnancy, % Reduced physical activity during pregnancy, % **Mid pregnancy** LTPA, min/wk - Light intensity - Moderate-intensity - Vigorous-intensity - Moderate-to-vigorous-intensity **Late pregnancy** LTPA, min/wk - Light intensity - Moderate-intensity - Vigorous-intensity - Moderate-to-vigorous-intensity	7 36 161 ± 197 109 ± 106 24 ± 56 133 ± 124 179 ± 197 92 ± 120 8 ± 32 99 ± 126
Meinilä et al. 2016* [32]	RADIEL intervention study (lifestyle counselling)	443 women with obesity or history with GDM	Gestational weeks of 12.5±1.9	LTPA during the last month inquired by a questionnaire	LTPA, min/wk	60 (30–140)

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
Rönö et al. 2018 [37]	RADIEL intervention study (lifestyle counselling)	231 women with obesity or history with GDM (only control group included)	Gestational weeks of 13 and 35 on average	Self-reported duration of LTPA that makes the participant at least slightly out of breath and sweating; 1-week physical activity diary	LTPA in baseline - Questionnaire, min/wk - Diary data, MET min/wk Change in median weekly LTPA between baseline and third trimester Change in MET min/wk between baseline and third trimester Meeting PA recommendation of 150 min/week in the third trimester, %	 60 (30–120)** 1376 ± 823 ↓ 22 (-10; -32) ↓ 182 ± 929 13.7
Pellonperä et al. 2019 [36]	FOPP intervention study (fish oil + probiotics)	110 women with overweight or obesity	Gestational weeks of 13.9±2.1 and 35.2±0.9	MET-index	MET, h/wk - early pregnancy - late pregnancy	 5.0 (2.0–12.0) 3.0 (0.2–11.0)
Pajunen et al. 2022 [35]		351 women with overweight or obesity GDM+ group: 81 women who developed GDM after the baseline visit GDM- group: 270 women who did not develop GDM	GDM+ 14.2±2.0 gw GDM- 13.8±2.1 gw	MET-index	MET-index, h/wk - GDM+ - GDM- Light PA level, % - GDM+ - GDM- Moderate PA level, % - GDM+ - GDM- High PA level, % - GDM+ - GDM-	 7.5 (3.0–12.0) 4.8 (3.0–12.0) 42 54 51 39 7 7

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	ASSESSMENT METHOD	VARIABLE	RESULT
Piirainen et al. 2006 [50]	Intervention study (dietary counselling + probiotics)	69 healthy and atopic women (only control group included)	All three trimesters	All episodes of aerobic physical activity exceeding 30 min a time obtained by interview	Weekly episodes of aerobic PA exceeding 30 min/time - First trimester - Second trimester - Third trimester Change in aerobic PA episodes/wk by the third trimester	 2.2 (0.9, 2.1) 1.5 (1.7, 2.8) 1.0 (0.5, 1.5) ↓ 1.3 (-2.0, -0.7)
Aittasalo et al. 2008 [65]	Intervention study (lifestyle counselling)	56 healthy pregnant women (only control group included)	Gestational weeks of 16-18 and 37	LTPA questionnaire modified from the International Physical Activity Questionnaire, IPAQ	**Early pregnancy** Light-intensity LTPA - days/wk - min/wk At least moderate-intensity LTPA - days/wk - min/wk **Late pregnancy** Light-intensity LTPA - days/wk - min/wk At least moderate-intensity LTPA - days/wk - min/wk	 3.8 ± 2.3 170 ± 181 4.0 ± 2.1 201 ± 144 4.7 ± 2.5 264 ± 295 2.9 ± 2.1 131 ± 127
Mäkelä et al. 2013 [34]	STEPS birth cohort study (observational follow-up study)	149 women with normal weight or overweight	Gestational weeks of 26-28	Self-administered questionnaire on leisure time activities, self-oriented PA, and frequency, type and duration of exercise	The mean exercise frequency, times/wk - normal weight - overweight Average duration of exercise, hours	 2-3 2 ± 1 2 ± 1 0.5–1

Data presented as n (%), mean ± standard deviation, median (lower−upper quartile) or mean difference (95% confidence interval lower bound, upper bound). In intervention studies, only the results of control group included in the table when possible. *One study reported similar results of the same study data with a smaller number of participants [44]. ** The results differ from those reported in [32] as they reported results of the intervention and control group together, whereas here, only the results from the control group are shown. GDM, gestational diabetes mellitus. gw, gestational weeks. IPAQ, International Physical Activity Questionnaire. LTPA, leisure time physical activity. PA, physical activity. MET, metabolic equivalent of task. ↓ denotes decrease.

2.1.3 Gestational weight gain

Recommendations for gestational weight gain

Mother's body undergoes significant changes during pregnancy in order to support the growing and developing foetus [66]. The development of new tissues, such as placenta and foetal tissue, and accumulation of adipose tissue and amniotic fluid increases the mother's body weight [67]. However, there are health risks related to these maternal body changes as excess gestational weight gain (GWG) has been linked with a higher risk for e.g. caesarean delivery, preterm birth, child macrosomia as well as maternal and childhood obesity later in life, whereas inadequate GWG may increase the risk for e.g. low birth weight [68–71]. To prevent these short-term and long-term health risks, the Institute of Medicine (IOM) has issued guidelines for GWG according to the mother's pre-pregnancy weight gain [67]. These guidelines are also adopted in the Finnish recommendations for GWG [29]. The GWG recommendations differ between the weight classes as the risk of health complications increases with increasing weight [67]. The recommended GWG and GWG rate are represented in Table 4. Recommended GWG for women with normal weight consist of around eight kilograms of water, one kilogram of protein and adipose tissue and other tissues of variable amounts [67]. Although the GWG rate is individual, most of the weight is typically gained in the second and third trimesters of pregnancy [67].

Table 4. Institute of Medicine's guidelines for total weight gain and rate of weight gain in the second and third trimesters [67]. Modified from Rasmussen *et al*, 2009.

PRE-PREGNANCY BMI (kg/m^2)	TOTAL WEIGHT GAIN (kg)	RATE OF WEIGHT GAIN (kg/wk)
<18.5	12.5–18.0	0.51 (0.44–0.58)
18.5–24.9	11.5–16.0	0.42 (0.35–0.50)
25.0–29.9	7.0–11.5	0.28 (0.23–0.33)
≥30.0	5.0–9.0	0.22 (0.17–0.27)

BMI; Body mass index.

Gestational weight gain in Finnish women

Findings from the previous studies assessing GWG in Finnish pregnant women are shown in Table 5. The timing and method for the weight assessment during pregnancy varied between the studies. The GWG was typically assessed using either pre-pregnancy or early pregnancy weight: the former was self-reported by the women and obtained from maternity card and the latter was weighted by the researchers in a study visit. Thus, it should be noted that the gestational time from which the GWG has been calculated vary greatly between the studies and contributes to inaccuracies when the values are compared to the recommendations.

Based on the Finnish studies, the mean GWG ranged from 9.1 to 14.9 kg [34,39,50,51,72–75]. The STEPS study reported that women with normal weight gained around 2 kg more weight during pregnancy than those with overweight [34], whereas the FOPP study found that women with overweight gained approximately 2 kg more weight during pregnancy than those with obesity [72]. It has also been reported that women with GDM gained around 3 kg less weight than women without GDM [51]. Two studies (both from the DIPP birth cohort study) determined the mean weekly GWG rate, which ranged between 0.34 and 0.43 kg/wk [51,73]. Women with GDM had lower GWG rate compared to those without GDM [51]; this result might be due to the regular clinical monitoring and health counselling received from the maternal health care during pregnancy.

The proportion of women having ideal GWG as defined in the IOM recommendations ranged from 12 to 43% [72,74,75]. Thus, most of the pregnant women had either inadequate or excess GWG during pregnancy. In a study with healthy primiparous women, one third had excess GWG [75], whereas in the NELLI study with women with increased risk of GDM, over half of the women had excess GWG [74]. Further, in the FOPP study, which included women with overweight and obesity, up to 64−77% of the women had excess GWG in kilograms and 84% had excess GWG rate [36,72].

Overall, the GWG is not in accordance with recommendations in a majority of pregnant women in Finland. The GWG is higher than recommended especially in women with overweight and obesity.

Table 5. Gestational weight gain in Finnish pregnant women.

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	METHOD USED FOR WEIGHT ASSESSMENT	VARIABLE	RESULTS
Pellonperä et al. 2021* [72]	FOPP intervention study (fish oil + probiotics)	439 women with overweight or obesity Intervention groups: Fish oil: n=109 Probiotics: n=110 Fish oil + probiotics: n=109 Control: n=110; No difference in GWG between the intervention groups	Gestational weeks of 13.8 ± 2.1 and 38.1 ± 2.1	Early pregnancy weight measured by researchers with a scale connected to BOD POD body composition assessment device. Pre-pregnancy weight (self-reported) and the last weight measurement (measured at antenatal clinic prior to delivery) assessed from the maternity card.	GWG from pre-pregnancy to the last measurement, kg Early pregnancy to the last measurement - all women - overweight - obesity GWG compared to IOM recommendation, % - Inadequate - Ideal - Excess GWG rate compared to IOM recommenda-tion, % - Inadequate - Ideal - Excess	13.0 ± 6.3 11.9 ± 4.9 12.8 ± 4.7 10.4 ± 4.9 10 26 64 6 10 84
Uusitalo et al. 2009 [73]	DIPP birth cohort study (observational follow-up study)	3360 women with children with type 1 diabetes risk gene	Retrospectively assessed from pregnancy time; on average the 10th and 39th gestational weeks	Weight gain information assessed from the maternity card. GWG rate calculated by dividing the weight gained by the number of weeks over which the weight was monitored.	GWG, kg GWG rate, kg/wk	12.4 ± 4.6 0.43 ± 0.15

REFERENCE	STUDY DESIGN	PARTICIPANTS	STAGE OF PREGNANCY	METHOD USED FOR WEIGHT ASSESSMENT	VARIABLE	RESULTS
Salmenhaara et al. 2010 [51]	DIPP birth cohort study (observational follow-up study)	3260 women with children with type 1 diabetes risk gene GDM+: Women with GDM, n=174 GDM-: no GDM	Retrospectively assessed from pregnancy time	Weight gain information assessed from the maternity card. GWG rate calculated by dividing the weight gained by the number of weeks over which the weight was monitored.	GWG, kg - GDM+ - GDM- GWG rate, kg/wk - GDM+ - GDM-	 9.4 ± 5.1 12.6 ± 4.5 0.34 0.43
Piirainen et al. 2006 [50]	Intervention study (dietary counselling +probiotics)	209 healthy and atopic women; Intervention: n=140 Control: n=69 No difference in the GWG between the intervention groups	Pre-pregnancy and third trimester (one week before delivery)	Total GWG calculated by subtracting self-reported pre-pregnancy weight from the last weight recorded at the prenatal visit or at hospital	GWG, kg	14.9 ± 4.9
Kinnunen et al. 2007 [75]	Intervention study (lifestyle counselling)	56 healthy pregnant women expecting their first child	Gestational weeks of 16–18 and 37	Weight, measured by nurses at maternity care visit, obtained from the maternity card	GWG, kg GWG compared to IOM recommendation, % - Inadequate - Ideal - Excess	14.3 ± 4.1 27 43 30
Kinnunen et al. 2012 [74]	NELLI intervention study (lifestyle counselling)	180 women with at least one GDM risk factor (only control group included)	Pre-pregnancy and gestational weeks of 36–37	Pre-pregnancy weight self-reported. Pregnancy weight measured at the study visit.	GWG, kg GWG compared to IOM recommendation, % - Inadequate - Ideal - Excess	14.3 ± 5.0 18 28 54
Korpi-Hyövälti et al. 2012 [39]	Intervention study (dietary counselling)	27 women with GDM risk factors (only control group)	Gestational weeks of 8–12 and 36–40	Weight measured by a nurse in well-women clinic visit	GWG, kg	13.9 ± 5.1

REFERENCE	**STUDY DESIGN**	**PARTICIPANTS**	**STAGE OF PREGNANCY**	**METHOD USED FOR WEIGHT ASSESSMENT**	**VARIABLE**	**RESULTS**
Mäkelä et al. 2013 [34]	STEPS birth cohort study (observational follow-up study)	149 women with normal weight or overweight	Pre-pregnancy and third trimester	Self-reported pre-pregnancy weight and measured pregnancy weight obtained from the maternity card. GWG defined by subtracting pre-pregnancy weight from that recorded at the hospital before delivery or at the last visit before delivery at well-women clinics.	GWG, kg - normal weight - overweight	 13.5 ± 4.0 11.5 ± 5.5

Data presented as n (%) or mean ± standard deviation. In intervention studies, only the results of control group included in the table when possible. *One study reported similar results of the same study data with a smaller number of participants [36]. GDM, gestational diabetes mellitus; GWG, gestational weight gain; IOM, the Institute of Medicine.

2.2 Diet in Finnish children

2.2.1 Dietary assessment in children

Several dietary assessment methods, e.g. food diary, FFQ and diet quality index, can be used to measure children's diet depending on the purpose of the assessment. Food diary can be used to accurately measure food and nutrient intake as the individual is asked to record all consumed foods and beverages, with details on e.g. portion sizes, cooking methods and product brands, for a certain period of time [76]. The method does not rely on memory, and it allows for high specificity in reporting the consumed foods in detail due to its open-ended nature [77]. It is also an advantage that (optimally) the portion sizes can be measured rather than estimated from memory [77]. However, one challenge in the prospective method is that the individuals may change, either consciously or unconsciously, their eating habits by consuming foods that they consider they should be eating or those that are easy to report [77]. Furthermore, food diary method requires high motivation from the respondent and is burdensome and time-consuming for both the respondent and the data collector [77]. Also, the method does not necessarily measure habitual intake accurately if the number of days assessed is low due to e.g. limited resources [77].

FFQ method measures the individual's habitual frequency of consuming food items or food groups for a longer period of time and, with addition of estimating portion sizes, it can be used to calculate energy and nutrient intakes [76]. As the food consumption is reported retrospectively, the subjects cannot alter their eating habits. However, misreporting is still possible as the FFQ depends strongly on the memory of the respondent and the individuals may report e.g. what they consider is socially desirable [77]. Although the FFQ is a less accurate nutrient intake assessment method compared to the food diary, it is also less time-consuming and burdensome to use [77].

Diet quality indices may be used to assess the individual's adherence to healthy diet or dietary recommendations in a more holistic way [78]. The indices provide a summary score of overall diet quality, but they cannot be used to measure exact intakes of foods and nutrients or the habitual food consumption as accurately as food diary or FFQ. Especially food-based diet quality indices, in which the scoring can be conducted without an additional method for nutrient calculations, are quick and easy to complete and score, which reduces the burden on both the respondent and the data collector [79]. The diet quality indices may be either defined theoretically, i.e. the questions are compiled based on the current nutrition knowledge, or derived empirically, i.e. the relevant questions are identified by using statistical methods and food consumption data of a certain study population [78]. In both methods, the process involves making choices related to e.g. the questions to be included, the cut-off values and the scoring, which is a potential source of error [78]. The empirical approach may include less subjective choices, but e.g. the quality of food consumption data and representativeness of the study population may pose another risk of error.

In general, several limitations are related to the assessment of diet in under 12-year-old children. For instance, the children's cognitive skills to remember their food consumption, to recognise the consumed food items as well as to evaluate the correct portion sizes is limited [80,81]. Children may also recall e.g. the consumption of their favourite foods more easily than other consumed foods [80,81]. For these reasons, parents are often used as surrogate reporters for their child's dietary intake to increase the accuracy of the data [77]. However, it is also a potential source of reporting error if e.g. parents report the foods and beverages the child has consumed in the day care or school [82]. Parents often don't know in detail what their children are eating outside the home and as children's food frequencies and portion sizes are not constant over time, this may lead to misreporting, most often underreporting, of the child's food consumption [80,81]. These issues need to be taken into consideration when assessing the children's diet.

2.2.2 Diet in preschool-aged children

Consuming a good quality diet with enough of energy-yielding nutrients, vitamins and minerals in childhood is essential for the child's healthy growth and development, but it also has impacts on child's health later in life [83,84]. Parents provide the food for the children and serve as role models, thus building a basis for the children's dietary habits in childhood and beyond. In Finland, all preschool-aged, i.e. 2- to 6-year-old, children are provided with versatile meals (breakfast, lunch and afternoon snack), which comply with the national dietary recommendations, if attending the day care system; this covers approximately 80% of the age group [85]. The national dietary recommendations for preschool-aged children are issued by the National Nutrition Council [28] and the National Institute for Health and Welfare [29]. Several demographic factors influence the quality of child's diet. Understanding the factors associated with diet quality might help in dietary assessment and when conducting lifestyle counselling e.g. in health clinics.

Only few studies have investigated diet quality and related demographic factors in preschool-aged children in Finland. The data collection of the studies has been conducted around a decade ago and, although the sample sizes are large, they are representative of certain regions of Finland, not the whole country. The STEPS study used a modified version of the Index of Diet Quality, originally validated in adults: 10 questions of the original 16 questions were chosen for the study, but the modified questionnaire was not validated [86]. In the DIPP study, the development and validation process of the Finnish Children Healthy Eating Index (FCHEI) was described, and the associations between children's diet quality and child and parental background factors were reported [87]. FCHEI is based on the consumption of health indicator foods, e.g. vegetables, fruits and berries, milk, spread and fish, and foods high in sugar calculated from the food diary, and the scoring is based on deciles of the consumption with highest scores given to those with consumption closest to the recommendations [87]. Further, the questions and scoring of FCHEI is different among children aged 1, 3 and 6 years [87].

The mean diet quality scores in children aged 2 and 5 years ranged between 5.98 and 6.33 points, respectively (out of maximum score of 10, Table 6) with older children having better diet quality scores [86]. Only 0.6% and 2.1% of the 2- and 5-year-old children, respectively, got the highest diet quality score [86]. Besides the children with older age, also children whose parents had high education and high income levels were more likely to have better diet quality [86]. Moreover, higher disadvantage in the neighbourhood was associated with lower diet quality in 2-year-olds, but not in 5-year-old children [86]. In turn, the DIPP study observed that being cared for at home, as opposed to day care, was associated with the lowest FCHEI quartile (represents poor quality diet) among 3- and 6-year-olds Finnish children [87]. Furthermore, low FCHEI scores in 3-year-olds were associated with living in a semi-urban area and with mother's low education and the habit of smoking during pregnancy among the 6-year-olds [87].

Also, food consumption has been studied in Finnish preschool-aged children, although the evidence is limited (Table 6). Moreover, the style of reporting the food consumption varies between the studies as some report the proportion of children consuming the particular food items on a daily or weekly basis [7,86,88] or the consumption compared to the dietary recommendations [86], while others report e.g. the proportion of children consuming the food items at least once during a 3-day period [89]. Further, the dietary data has been assessed with different methods e.g. diet quality indices, food diary or FFQ. Thus, comparing the results between the studies is challenging. However, the findings suggest that a somewhat low proportion of preschool-aged children adhere to the dietary recommendations regarding the consumption of vegetables, fruits and berries, fish, low-fat milk and vegetable oil-based spreads.

It has been reported previously that less than half of the children met the Finnish dietary recommendations for consuming vegetables, fruits and berries [86] e.g. 250 g or five portions of their own palm size per day [29]. The DIPP study found that vast majority of children consumed vegetables, fruits and berries at least once during the three-day period of fulfilling the food diary [89], indicating however that some children did not consume any vegetables, fruits and berries during this time period. Another study from the same DIPP study data with a smaller number of subjects (n=461) reported that the prevalence of consuming vegetables and fruits, but not that of berries, was higher in children cared for outside home (94%, 79% and 12% respectively) compared to those in home care (79%, 70% and 16% respectively) [90]. Moreover, raw vegetables and fruits have been most commonly used almost on a daily basis, while cooked vegetables and berries were used less often [88]. The DAGIS study also showed that two thirds of the preschool-aged children consumed fresh vegetables and half of the children consumed fresh fruits daily, while only 7% of children used berries daily [7].

In the DIPP study, less than half of the children were reported to consume fish dishes at least once during the 3-day recording period [89] and in the STEPS study, only one third of 2-year-olds and half of 5-year-olds consumed fish 2–3 times a week as recommended [86]. Most children (79%) have found to consume fish at least sometimes [7]. The recommended option of vegetable oil-based spread with fat content of more than 60% was consumed by only one third of children [86]. Other studies did not report the consumption of specifically vegetable oil-based spread, but the DIPP study reported that margarines with fat content of at least 55% was consumed by half of the children [89]. Small children are recommended to consume 20−30 g of visible fat per day, e.g. 1.5–2 tablespoons of vegetable oil or 4–6 teaspoons of vegetable margarine [29].

Furthermore, only around half of the children consumed skimmed milk [7,89] and around two thirds consumed low fat dairy products with the fat content of max 1% [86]. For small children, the recommended daily consumption of dairy products is 4 dl of liquid milk products with the fat content of max 1% and one slice of cheese with at most 17% of fat [29]. Also, according to the STEPS study, almost all of the children ate breakfast daily and more than two thirds of the children had a regular eating frequency, i.e. consumed 4−5 meals a day [86].

In addition to diet quality and food consumption, one study has also investigated dietary patterns in Finnish preschool-aged children [91]. In a study with 3–6-year-old children (n=756) three dietary patterns were identified: 'Sweets-and-treats' (high loadings of e.g. biscuits, chocolate, ice cream and soft drinks), 'Health-conscious' (high loadings of e.g. nuts, yoghurt, berries and wholegrain porridge) and 'Vegetables-and-processed meats' (high loadings of e.g. fresh vegetables and fruits, cold cuts and wholegrain bread) [91]. Some studies have also investigated food and nutrient intakes in preschool-aged children, but this thesis aims to investigate the quality of diets, and thus specific dietary intakes are out of the scope of this thesis.

To conclude, the previous evidence suggest that the diet of preschool-aged Finnish children does not reach the recommendations and the challenges, namely the low consumption of vegetables, fruits and berries, fish, skimmed milk and vegetable oil-based spread, are similar to those of Finnish adults. Nonetheless, we could benefit of more timely information on the quality of preschool-aged children's diet and associated demographic factors especially within a nationwide sample of the age group. Furthermore, more information on the children's consumption of health indicator foods, e.g. vegetables, fruits and berries, fish, low-fat dairy products and vegetable oil-based spreads, are called for.

Table 6. Diet quality and food consumption in preschool-aged Finnish children.

REFERENCE	STUDY DESIGN	PARTICIPANTS	AGE (YEARS)	METHOD USED FOR DIETARY ASSESSMENT	VARIABLE	RESULT
Tarro et al. 2022 [86]	STEPS birth cohort study (observational follow-up study)	888 children	2 and 5	Modified version of the adult's IDQ; 10 dietary items used to form a diet quality score, each recommended choice provided 1 point for the score; score range of 0−10	**Diet quality score**	
					- 2-year-olds	5.98 ± 1.72
					- 5-year-olds	6.33 ± 1.66
					Consumption, %	Age group (y): 2 / 5
					Breakfast daily	93 / 97
					Having 4-5 meals daily	75 / 71
					(Plant) milk/sour milk with meals	90 / 92
					Low fat dairy (≤1% fat)	68 / 66
					Water as primary beverage	76 / 80
					Spread (>60% unsaturated fat)	37 / 33
					Fish 2–3 times/wk	32 / 54
					Vegetables ≥2 times/day	40 / 49
					Fruits and berries ≥2 times/day	41 / 46
					Unhealthy snacks ≥1 time/wk	51 / 48
Kyttälä et al. 2010* [89]	DIPP birth cohort study (observational follow-up study)	1968 children	2–4 and 6	3-day food diary	**Consumption at least once during the 3-day period, %**	Age group (y): 2 / 3 / 4 / 6
					Fruits and berries	92 / 95 / 91 / 94
					Vegetables	81 / 91 / 89 / 92
					Rye bread	65 / 75 / 77 / 80
					Mixed wheat bread	69 / 81 / 76 / 84
					White bread	45 / 47 / 57 / 49
					Skimmed milk	44 / 55 / 56 / 62
					Low-fat milk (≤2% fat)	76 / 76 / 79 / 76
					Whole milk (>2% fat)	5 / 9 / 10 / 8
					Butter	33 / 39 / 42 / 42
					Margarine ≥55% fat	47 / 62 / 67 / 70
					Margarine <55% fat	25 / 37 / 31 / 35
					Fish dishes	40 / 46 / 49 / 48
					Sweetened fruit drinks	74 / 79 / 86 / 76
					Fruit juice	46 / 49 / 43 / 46

REFERENCE	STUDY DESIGN	PARTICIPANTS	AGE (YEARS)	METHOD USED FOR DIETARY ASSESSMENT	VARIABLE	RESULT
Korkalo et al. 2019 [7]	DAGIS; cross-sectional survey	864 children	3–6	3-day food diary kept by the parents and the preschool personnel about all foods and drinks the child consumed during the day	**Daily consumption, %** Fresh vegetables Fresh fruits Berries Skimmed milk/sour milk 1% or semi-skimmed milk Low-fat cheese High fat cheese Sugar-sweetened juice Plain nuts, almonds and seeds Fish and fish products **Consumption less than daily, %** Berries Plain nuts, almonds and seeds Fish and fish products	 69 51 7 43 46 14 27 8 3 0.4 63 25 79
Lehto et al. 2019 [92]		585 children	3–6	2-day food diary of preschool meals (breakfast, lunch and afternoon snack)	Fruit consumption during the study period at preschool, %	63
Kähkönen et al. 2020 [88]	Cross-sectional survey	114 children	3-5	FFQ	**Consumption, %** Raw vegetables - Twice a day or more - 5–7 times/week - 2–4 times/week - Once a week or less	 24 49 25 2

REFERENCE	STUDY DESIGN	PARTICIPANTS	AGE (YEARS)	METHOD USED FOR DIETARY ASSESSMENT	VARIABLE	RESULT
					Cooked vegetables	
					- Twice a day or more	4
					- 5–7 times/week	22
					- 2–4 times/week	40
					- Once a week or less	33
					Berries	
					- Twice a day or more	1
					- 5–7 times/week	18
					- 2–4 times/week	46
					- Once a week or less	35
					Fruits	
					- Twice a day or more	19
					- 5–7 times/week	54
					- 2–4 times/week	25
					- Once a week or less	2

Data presented as % of participants or mean ± standard deviation. *One study reported similar results of the same study data with a smaller number of participants [90]. FFQ, Food frequency questionnaire; IDQ, the Index of Diet Quality.

2.2.3 Diet in elementary school-aged children

Elementary school-age is an important phase for the development of child's dietary habits as the children will become more independent at eating and selecting the foods they want to eat as they grow older. This may result in a lower diet quality compared to younger ages [93–95]. In addition to the daily meals provided at home, all elementary school-aged, i.e. 7- to 13-year-old, children are provided with a versatile warm meal every school day within the Finnish school system in order to support the children's wellbeing, growth and development. These meals are an integral part of child's diet and they comply with the national dietary recommendations for school-aged children issued by the National Nutrition Council [28] and the National Institute for Health and Welfare [29].

Only two studies have investigated diet quality in Finnish elementary school-aged children (Table 7); these studies cover children aged 6 to 8 years, but there is a scarcity of published data from older children in elementary school-age. Furthermore, the existing studies, based on data from the Physical Activity and Nutrition in Children (PANIC) study and the First Steps study, have reported children's diet quality measured with indices developed for adult populations (e.g. Baltic Sea Diet Score [96] and The Dietary Approaches to Stop Hypertension, DASH [97]) or for assessing diet in a different food culture (Mediterranean Diet Score, MDS) [98]. Moreover, Finnish Children Healthy Eating Index (FCHEI), used for assessing diet quality in elementary-school aged children [99], has been developed and validated for preschool-aged children [87], but whether it is valid to use in elementary school-aged children is not known. Thus, it is hard to draw conclusions of the existing data on diet quality of this age group in Finland. Furthermore, the food consumption has been reported with different methods: some studies report the daily consumption as a percentage of consumers [6,8] or the proportion of children consuming food items according to the recommendations [5], while others report the consumption frequency of food items as times per week [100]. The methods for assessment (food diary, FFQ or a short questionnaire on food consumption) as well as the assessed food items also vary between the studies, e.g. some studies report the consumption of skimmed or low-fat milk/sour milk [5,100] and others the overall consumption of milk [6]. Therefore, the results are not directly comparable.

In the previous studies (Table 7), the mean Baltic Sea Diet scores ranged from 11.4 to 11.8 with the maximum score being 24 [99,101], whereas the mean DASH score was 21.0 out of the maximum score of 35 [101]. The mean MDS scores were 3.8 (out of the maximum score of 8) and the mean FCHEI scores 22.9 (out of the maximum score of 45) among the children [99]. The diet quality measured with the DASH score was lower in boys than in girls [101].

Four studies have also investigated the food consumption in elementary school-aged children (Table 7). Over a decade ago less than five percent of 6–8-year-old children consumed vegetables, fruits and berries five portions a day as recommended [5]. Other studies reported that only one third consumed vegetables or fruits daily [6,8,102] and over half of the children did not consume neither vegetables nor fruits on a daily basis [8]. Moreover, International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) reported that children consumed vegetables, fruits and berries only about five times per week [100]. In the PANIC study, less than half of the children consumed fish at least two times per week [5]. In line with this finding, ISCOLE study reported that the children consumed fish around 1.7 times per week [100]. Two thirds of the children were also found to consume the recommended option of skimmed milk or sour milk [5], whereas skimmed or low-fat milk was consumed on average once a day [100]. Furthermore, two thirds of the children consumed vegetable oil-based spread on bread and most of the children consumed rye or wholegrain bread [5]. In turn, ISCOLE study reported that wholegrain foods were consumed approximately six times a week [100]. One third of children has also been reported to consume sugary beverages on a daily basis [5]. Three studies investigated the consumption of sugary soft drinks in particular and found that they were consumed on average 1.3 times per week [100], while 2−5% of children consumed sugary soft drinks daily [6,8,102]. Moreover, majority of children ate breakfast daily [6,8,102], but having a daily meal with family was not as common [8,102]. Three out of four children also had a regular meal pattern, i.e. they had lunch and dinner every school day [6].

Two studies have also investigated dietary patterns in this age group of Finnish children. In the Finnish Health in Teens (Fin-HIT) study, three dietary patterns were identified in 9−14-year-old children (n=10569): ‘Unhealthy eaters’ (12% of the children), ‘Fruit and vegetable avoiders’ (43% of the children), and ‘Healthy eaters’ (44% of the children) [6]. The ‘Unhealthy eaters’ were characterised by a higher consumption of fast food, sweet and savoury baked goods, ice cream, salty snacks and sugary beverages [6]. The ‘Fruit and vegetable avoiders’ consumed less unhealthy foods, but also the lowest amount of e.g. vegetables, fruits and berries and fresh juice [6]. The ‘Healthy eaters’ characterised by a higher consumption of dark grain bread, milk, fresh vegetables, fruits or berries, fresh juice, and a low consumption of the unhealthy food items [6].

In the ISCOLE study involving Finland and 11 other countries, two dietary patterns were identified among 9−11-year-old children (n=7199 of which 535 from Finland): ‘Unhealthy diet pattern’ with higher loadings for fast foods, potato chips, ice cream, cakes and sugary beverages as well as ‘Healthy diet pattern’ with higher loadings for e.g. vegetables, fruits and berries [100]. The patterns were similar in all of the countries [100]. The mean scores for the ‘Unhealthy pattern’ were the lowest in Finnish children as compared to the other countries, indicating that the pattern was the least predominant in Finland [100]. However, the scores for the 'Healthy pattern' were also lower than the overall average of all the countries [100].

All in all, the dietary habits of elementary school-aged Finnish children have not been studied widely and the reporting methods differ between the existing studies. The previous findings suggest that the diet of elementary school-aged children is not in an optimal level compared to the recommendations. The typical challenges in the diet, previously presented in Finnish adults and small children, namely the low consumption of vegetables, fruits and berries, fish, skimmed milk and vegetable oil-based spread, are also represented in the diet of this age group of Finnish children. Only little evidence also exists on the demographic factors associated with child's diet. Furthermore, data of the existing studies has mostly been gathered over 10 years ago. Thus, timely information on the diet of elementary school-aged children is needed.

Table 7. Diet quality and food consumption in elementary school-aged Finnish children.

REFERENCE	STUDY DESIGN	PARTICIPANTS	AGE (YEARS)	METHOD USED FOR DIETARY ASSESSMENT	VARIABLE	RESULT
Haapala et al. 2017 [99]	Data gathered in two studies: 1) PANIC; intervention study (lifestyle counselling) and 2) First Steps; population-based observational follow-up study	161	6−8	4-day food diary	Baltic Sea Diet Score Mediterranean Diet Score Finnish Children Healthy Eating Index	11.4 ± 4.2 3.8 ± 1.4 22.9 ± 6.5
Haapala et al. 2015 [101]	PANIC; intervention study (lifestyle counselling)	428	6−8	4-day food diary	Baltic Sea Diet Score DASH score	11.8 ± 4.4 21.0 ± 4.4
Eloranta et al. 2011 [5]		424	6−8	4-day food diary	**Consumption, %** Vegetables, fruits and berries, ≥5 portions per day Fish ≥2 times per week Vegetable oil-based spread on bread, <70% of fat Rye or wholegrain bread, ≥5% of fibre Skimmed milk or sour milk Sugar-sweetened drinks daily	girls / boys 4 / 4 42 / 44 74 / 67 88 / 88 63 / 67 27 / 29
Mikkilä et al. 2015 [100]	ISCOLE; a multinational observational study; only data from Finnish children is reported here	535	9−11	FFQ	**Consumption frequency, times/week** Vegetables Fruits and berries Wholegrains Fish Skimmed milk or low-fat milk Sugar-sweetened sodas Sweets (candy/chocolate)	 5.0 ± 3.2 4.9 ± 3.1 5.9 ± 3.1 1.7 ± 2.0 7.0 ± 3.8 1.3 ± 1.4 1.8 ± 1.6
De Oliveira Figueiredo et al. 2019 [6]	Fin-HIT; a prospective school-based cohort study	10569	9−14	FFQ	**Consumption, %** Fresh or grated vegetables/ salad daily Cooked vegetables daily Fruits or berries daily Milk or soured milk daily	 40 9 33 66

REFERENCE	STUDY DESIGN	PARTICIPANTS	AGE (YEARS)	METHOD USED FOR DIETARY ASSESSMENT	VARIABLE	RESULT
					Dark grain bread daily Soft drink ≥5 times a week Regular breakfast pattern Regular meal pattern (lunch and dinner every school day)	29 5 81 76
Inchley et al. 2020 [8]	Health Behaviour in School-aged Children (HBSC); a WHO collaborative cross-national survey; only data from Finnish children is reported here, reporting period 2017−2018	N/A	11	Structured questionnaire on eating habits	**Consumption, %** Breakfast every weekday Having a daily meal with family Fruit daily Vegetables daily Eating neither fruit nor vegetables daily Sweets daily Sugared soft drinks daily	girls / boys 73 / 77 31 / 50 29 / 23 35 / 29 55 / 64 3 / 3 2 / 5
Inchley et al. 2016 [102]	Reporting period 2013−2014				**Consumption, %** Breakfast every weekday Having a daily meal with family Fruit daily Vegetables daily Sweets daily Sugared soft drinks daily	girls / boys 75 / 81 33 / 39 31 / 24 33 / 29 1 / 2 1 / 3

Data presented as % of participants or mean ± standard deviation. DASH, Dietary Approaches to Stop Hypertension; WHO, the World Health Organization.

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2.3 Maternal and child lifestyle habits in other Western countries

Many different factors, including cultural, social, societal and environmental factors, influence the daily life and lifestyle habits of individuals. Therefore, the lifestyle habits in pregnant women and children naturally somewhat differ among countries. In general, the recommendations regarding lifestyle habits during pregnancy in different countries are based on scientific evidence, and thus have similarities, but are also often tailored for the needs of different populations, e.g. dietary recommendations differ based on geographic location or food culture. To get an overview of the potential similarities and differences in the lifestyle habits of pregnant women and children among developed countries, the Finnish data was compared to that from pregnant women and children living in other Western countries, e.g. in Europe, the United States (US), Canada and Australia.

2.3.1 Lifestyle habits in pregnant women in other Western countries

2.3.1.1 Diet

Diet quality during pregnancy has been widely studied in Western countries, such as the US, Canada and Australia, whereas the adherence to the Mediterranean diet (MD) during pregnancy has been of interest especially in the Mediterranean area. For these purposes, several indices assessing the diet quality have been used in assessing diet during pregnancy. These include e.g. the Healthy Eating Index (HEI), used for assessing the adherence to American dietary recommendations [104], and its modifications for different diet cultures and study populations, such as Alternative HEI (AHEI) which is assessing whether diet is reducing the risk of chronic disease [105], AHEI-P which is a modified version of AHEI for pregnancy time [106], and C-HEI modified to reflect Canadian dietary recommendations [107]. Other indices used include e.g. the Diet Quality Index for Pregnancy (DQI-P) developed for American population [108], the Canadian Diet Quality Index for Pregnancy (DQI-P_c) which assesses the adherence to Canadian dietary guidelines [109], the Australian Recommended Food Score (ARFS) measuring the adherence to Australian dietary recommendations [110] and New Nordic Diet (NND) score for measuring the adherence to Nordic Nutrition Recommendations [111]. Further, in the Mediterranean area the diet quality has been investigated with the adherence to MD with using e.g. the MDS [98] and its modifications such as the Mediterranean Diet Score for pregnant women (MDS-preg) [112], the Mediterranean Diet Serving Score (MDSS) [113], the Relative Mediterranean Diet score (rMED) [114] and the Alternative Mediterranean Diet score (aMED) [115]. Scientific evidence indicates that there is room for improvement in the diet quality of pregnant women also in other Western countries. The challenges are similar to those of Finnish pregnant women, e.g. low consumption of vegetables, fruits, fish and whole grains [38–40].

The mean HEI scores in pregnant population have ranged between 51 and 75 points out of a maximum of 100 points [116–125]. In US women, good diet quality (HEI scores ≥60) was recorded in half of the women in early pregnancy, but only in one third of the women in mid-pregnancy [119], whereas in another study three-quarters of US women had good diet quality by using a cut-off value of 68.3 [125]. Yet another study with US women found that one third of the women had good diet quality (HEI scores ≥80) [118]. In an Australian study, one third of the women had poor diet quality (HEI scores >50) [122]. Moreover, a Spanish study reported a median AHEI score of 61 points out of maximum of 100 points with 29% having a high adherence to the recommended diet (AHEI score ≥65) [126]. Two US studies using AHEI-P reported the mean score of 61 points out of a maximum of 90 points [127,128], while a third study showed a mean score of 42 out of a maximum of 80 points [129]. In three Canadian studies, the mean C-HEI scores ranged between 63 and 67 points of out a maximum of 100 points [130–132]. As for the ARFS, three Australian studies reported the mean scores ranging between 29 and 32 points out of a maximum of 72; these scores show a relatively low adherence to the Australian dietary recommendations [133–135]. Furthermore, the mean DQI-Pc scores for Canadian pregnant women were 77 points out of a maximum of 100 points [109]. In a Norwegian study, the investigators reported a mean NND score of 4.9 points out of a maximum of 10 points with 39% of the women having a high diet quality score [136]. Moreover, only 3% of Swedish pregnant women were reported to have a high-quality diet, that is, they received at least 9 points from a maximum of 12 points assessed by a Swedish diet quality index [137].

Regarding the adherence to the MD, the mean score of MDS was 4.3 points and the mean score of MDS-P was 7.5 (out of a maximum of 11 points) in Spanish women [138], whereas the mean scores for the MDS-preg were 2.7 out of a maximum of 8 points in US women and 3.8 points in Cretan women [112]. Additionally, in Croatian women, the median MDS-preg score was 3.6 out of maximum of 10 points and the median MDSS score was 10 (out of maximum of 23 points) with only 28% of women having a good compliance to MD (cut-off of 13.5 points) [139]. Lastly, the median of aMED scores was 4 points out of maximum of 8 points and the median of rMED scores was 8 points out of maximum of 15 points; 19% and 9% of the women had a high adherence to the MD as assessed by aMED and rMED, respectively [126].

The adherence to the recommended consumption of the health indicator foods, e.g. vegetables, fruits and berries, fish and milk, based on previous findings in selected Western countries is shown in Figure 2. The studies show that the consumption of vegetables and fruits is fairly low during pregnancy in Western countries. For example, only one out of five Croatian women consumed vegetables as recommended [139]. Approximately one third of Canadian women and half of British women met the recommended consumption of fruits and vegetables [109,132,140], whereas in an Australian study, only 10% adhered to vegetable recommendation, but half of the women adhered to that for fruits [141]. Moreover, in Sweden, around two thirds of pregnant women consumed vegetables and fruits daily [142], while in Spain, only a fraction of the pregnant women consumed vegetables and fruits daily [143].

Also, the consumption of whole grains and grains overall could be improved in Western population of pregnant women. In the US, 5−54% of the women have met the recommendation for whole grains [119], whereas in Canada, 5% and 12% have met the recommended consumption of whole grains and grains, respectively [109,132]. In New Zealand, one out of four pregnant women consumed breads and cereals per day as recommended [144], and in Australia, only 4% of the women consumed grains as recommended; however, 70% of the women consuming bread usually chose high-fibre bread over white bread [141].

As for the dairy and milk consumption, 15−58% of the pregnant women adhered to the recommended consumption in the US and in Canada [119,121,132]. Similarly in Australia and New Zealand, 29−58% of the women consumed dairy products according to the recommendations [141,144]. Half of the Australian women consuming dairy products chose the low-fat option in milk and yoghurt and one third in cheese products [141]. Further, a Spanish study reported that half of pregnant women consumed whole milk and/or other dairy products on a daily basis, which is the recommended option in Spain [143].

Also, the consumption of fish seems to be low during pregnancy, e.g. only one out of five women in the US and one out of four women in Croatia and the United Kingdom (UK) met the recommended amount [139,145,146]. In Poland, almost half of women consumed fish on a weekly basis, whereas in the Netherlands, one out of four women consumed fish at least weekly [147,148]. However, only 2% of Spanish women consumed fish on a weekly basis [143].

Previous studies have also indicated that it is somewhat common to have an irregular meal pattern, i.e. skip some of the main meals of the day (breakfast, lunch, dinner). In a US study, one third of the participants skipped at least one main meal per day [116], whereas another US study reported that 13% of women routinely skipped at least one daily meal in late pregnancy [149]. Yet another US study found that it was most common to skip breakfast; this was done by 40% of women at least two times per week, while 15% and 3% of women skipped lunch and dinner as often, respectively [120]. In a German study, 27% of the women had irregular meal pattern [150]. Interestingly, it was common among Irish women with overweight or obesity to have a meal pattern dominant with main meals in early pregnancy (85%), whereas a snack dominant meal pattern was more common in late pregnancy (69%) [151]. Overall, the diet quality and consumption of foods relevant for health could be improved among pregnant women living in Western countries.

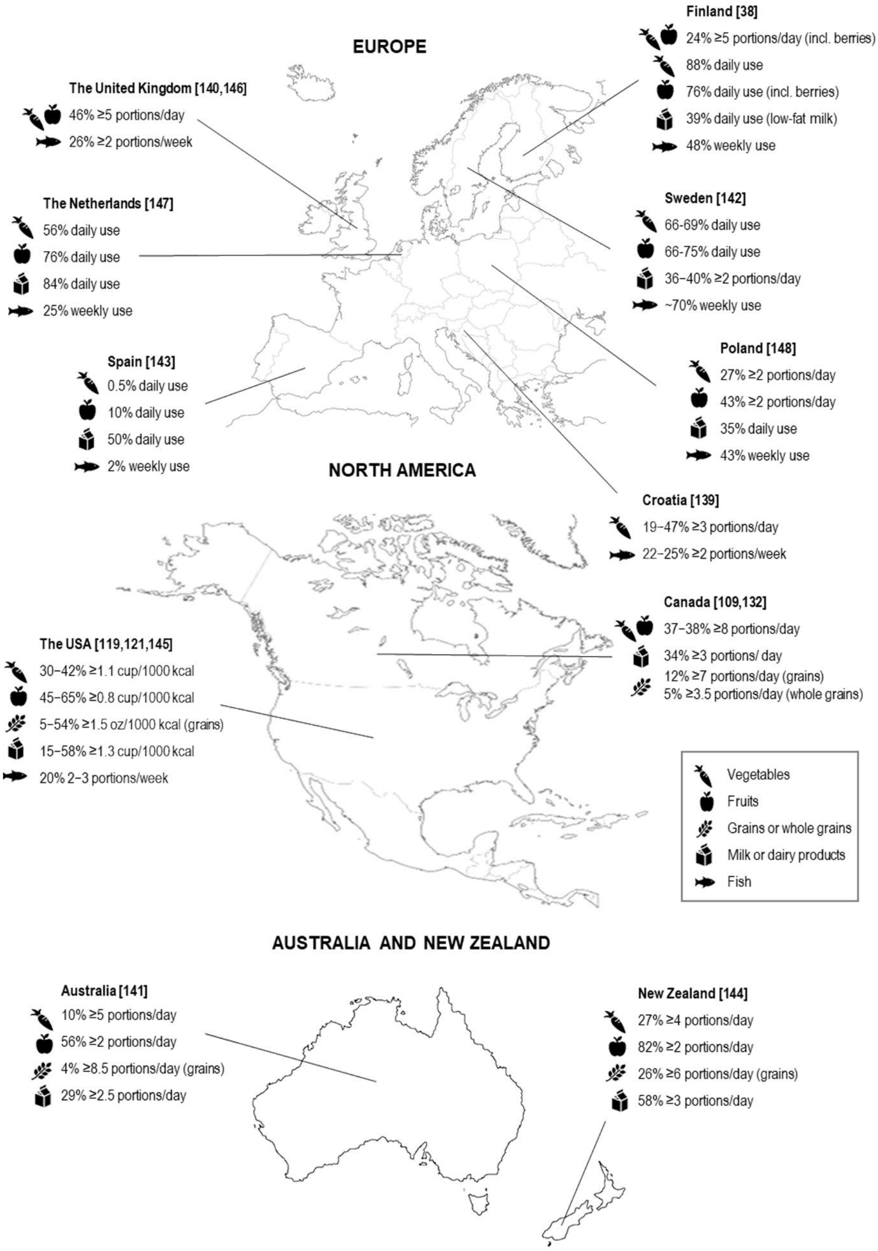

Figure 2. Proportions of pregnant women consuming vegetables, fruits, grain products, dairy products and fish in selected Western countries.

2.3.1.2 Food supplement use

International studies on the use of food supplements during pregnancy have observed similar findings compared to the Finnish studies. The data of these studies are mostly gathered within cohort or lifestyle intervention studies, in which the supplement use was not the primary topic of interest. The previous studies indicate that, similarly to Finnish studies, the prevalence of food supplement use during pregnancy in other Western countries range between 65 and 94% [52,130,152–162]. The multivitamin/multimineral supplement has been reported being the most commonly used food supplement product during pregnancy [130,155–158], the use of which has also been common among Finnish pregnant women [35,50]. Moreover, a multinational study conducted in nine European countries reported a wide variation in the supplement use between the countries, e.g. the prevalence of using folic acid supplements ranged from 56% in Lithuania to 98% in Spain [163]. Another multinational study conducted in the US, Sweden, Finland and Germany reported that the prevalence of using vitamin D-containing supplements ranged from 33% in Germany to 81% in the US [52]. Additionally, the quantitative supplement intake during pregnancy has not been studied as comprehensively as the prevalence of use, especially in the Europe. The existing studies reporting daily supplement intakes mostly concentrate on specific nutrients, such as vitamin D, folate or iron [155,156,160], but there is a lack of comprehensive data on the daily intakes of several nutrients from food supplements. Although it is essential to understand whether the pregnant women adhere to the recommendations and the tolerable upper intake levels of several food supplements (also other than folic acid supplements), only few studies have touched upon this issue. A Canadian study found that the adherence to the supplement recommendations was fairly high (70−90%) for folic acid, vitamin D and calcium, but low for iron (<30%) [156]. Further, one out of four women exceeded the tolerable upper intake level for folic acid and one out of five women for iron [156]. Further research on the issue is needed in the European level to ensure the optimal use of food supplements in order to reduce the risks related to the suboptimal or excess use of supplements during pregnancy.

2.3.1.3 Physical activity

Similar to the Finnish studies, the existing literature among women living in other Western countries suggest that the physical activity levels are lower than recommended among pregnant women. According to a systematic review, both the frequency and intensity of physical activity tend to decline towards the third trimester [164]. In a Dutch study, over half of the participants self-reported that their physical activity levels declined as the pregnancy proceeded, although the women indicated being motivated to perform physical activity during pregnancy [165].

Physical activity during pregnancy has been measured with several approaches, e.g. using accelerometers or questionnaires, and reported as steps taken per day, minutes or hours per day spent at physical exercise, metabolic equivalent of task (MET) minutes or hours per day or week or as proportions of women adhering to the physical activity recommendations.

According to the previous literature, the mean time spent with moderate-to-vigorous physical activity has varied between 12−32 minutes per day in the first trimester and between 8−27 minutes per day in the third trimester [166–169]. Moreover, the mean of 14 minutes per day was spent with moderate-to-vigorous physical activity in the second trimester [168]. The mean time of moderate-to-vigorous physical activity in sessions of at least 10 minutes was 95 minutes per week among Spanish women [170]. In a Norwegian study, the mean accumulated daily moderate-to-vigorous physical activity for women with western ethnicity was approximately 1.2 hours during weekdays and 1 hour during weekend days [171], while a French study reported a mean of 1.4 hours per day of accumulated daily moderate-to-vigorous physical activity in obese women [172]. In a US study, the mean time spent at light physical activity was approximately 3 hours per day in both early and late pregnancy [169]. Furthermore, in a Swedish study, the mean time spent at light physical activity was 198 and 210 minutes per day in early and late pregnancy, respectively [166].

When assessing the physical activity as steps taken per day, the mean of 7878 steps per day in the first trimester and 6273 steps per day in the third trimester were reported among Canadian women [173]. In the Norwegian study, women with western ethnicity walked a mean of 9603 steps per weekday in early pregnancy [171], and in a Spanish study, women in their early pregnancy took a mean of 7745 steps per day [170]. Individuals taking 5000–7499 steps per day can be considered as ‘low active’ and those taking 7500–9999 steps per day as ‘somewhat active’ [174].

Some studies have also reported the mean MET hours per week during pregnancy. The mean MET hours per week among Spanish pregnant women were 17 in the first, 14.1 in the second and 13.2 in the third trimester [175]. In an Italian study, the median MET hours per week were 4 in early pregnancy, 6.7 in mid-pregnancy and 6 in late pregnancy [176].

There seems to be a somewhat low adherence to the physical activity recommendations during pregnancy. In Italy, less than 5% of the women performed physical activity according to recommendations of the American College of Obstetricians and Gynaecologists (ACOG; ≥150 minutes per week of moderate physical activity) in the third trimester [177], whereas in the Netherlands, 31% and 12% of the participants met the ACOG recommendations in early and late pregnancy, respectively [167]. Another study stated that one out of four Spanish women adhered to the physical activity recommendation of ≥150 minutes per week of moderate physical activity in their second trimester [170]. Further, 46% and 28% of US women met the guideline of ≥150 minutes of moderate-to-vigorous physical activity in sessions of at least ten minutes in early and late pregnancy, respectively, but when using a definition of ≥150 minutes of accumulated moderate-to-vigorous physical activity, up to 65% and 61% of women met the guideline in early and late pregnancy, respectively [169]. In another US study, a third of the women engaged in ≥150 minutes of physical activity per week, but more than one out of four women performed less than 60 minutes of physical activity during the week [178]. Interestingly, in a Spanish study the proportion of women who complied with the physical activity recommendation (≥15 minutes of vigorous physical activity or 30 minutes of moderate physical activity for a minimum of five days per week) was 55% in the first trimester and later enhanced to 62% in the second and 59% in the third trimester [175]. Moreover, around half of the women were considered having a low physical activity level throughout the pregnancy [175].

Although physical activity during pregnancy has been evaluated and reported in different ways and the recommendations on physical activity may vary between the countries, the overall result seems to be similar across the studies: physical activity levels of pregnant women are lower than recommended and improvements are needed to support the healthy pregnancy.

2.3.1.4 Gestational weight gain

Previous literature on GWG in Western countries has demonstrated similar findings than those conducted in Finland; large proportions of pregnant women have either inadequate or excess GWG as compared to the IOM recommendations. In addition, it is common in Western countries that women with overweight or obesity gain weight in excess during pregnancy. Overall, it has been reported that 17−40% of women gain weight during pregnancy according to the recommendations, while 28−74% have excess GWG [135,179–188]. However, as the GWG recommendations vary according to the BMI categories by WHO [189], it is convenient to examine the situation within the different BMI categories.

In women with underweight, the GWG has been in accordance with the recommendations in 26−51% of the women, whereas 20−69% have been reported having inadequate GWG [179,183,188,190]. Among women with normal weight, 35−47% have had ideal GWG [179,183,185,188,190]. Furthermore, several studies have shown that the mean/median total GWG, ranging from 12.1 to 14.7 kg, has fallen within the recommended GWG range [135,187,190–192]. However, 9−67% of women with normal weight have had excess weight gain according to the literature [178,179,183,186,188,190]. Previous findings on the GWG in women with overweight or obesity have shown that 34−84% of the women gain more weight than recommended [178,179,183,185,186,188,193,194], and the GWG has been ideal in only 19−41% women [179,183,188,190,193–195]. On the other hand, it has also been reported that some obese women did not gain any weight or even lost weight during pregnancy [192,193,196].

The high proportions of excess GWG in all BMI categories across the developed countries suggest that there indeed is a need for more efficient means for supporting the healthy weight gain in all women to further support the health of both the mother and the foetus.

2.3.2 Diet in children in other Western countries

2.3.2.1 Diet in preschool-aged children

In Western countries, diet quality of preschool-aged children has been examined with several indices including e.g. the HEI used mostly in children from the US but also in other populations [94,197–199], the Diet Quality Index (DQI) for preschoolers based on the Flemish dietary guidelines [200] as well as the DQI assessing adherence to Dutch, German, Irish, Flemish, and the US dietary guidelines for preschoolers [201] and its modification the DQI-C assessing the adherence to Canadian dietary guidelines [202]. Diet quality has also been reported with the Diet Quality Index Score (DQIS) originally developed in the US for infants and toddlers and later modified for preschool-aged children [203] as well as with the Revised Children's Diet Quality Index (RC-DQI) developed in the US for preschool-aged children [204] and a modified version for Australian preschoolers [205]. Adherence to the MD has also been investigated with the KIDMED index [206] and the food frequency-based Mediterranean Diet Score (fMDS) [207], both validated for children. As in Finland, the quality of diet in preschool-aged children also in other Western populations needs improvements especially in meeting the recommended amount of e.g. vegetables, fruits, grain products, dairy and fish.

Diet quality scores as assessed by the HEI in preschool-aged children living in Western countries indicate a need for improvement; the mean HEI scores have ranged from 47 to 68 points out of a maximum of 100 points with scores less than 80 indicating moderate or poor diet quality [94,198,199,208–213]. Further, 11% of US children had good diet quality [209], whereas only 0.4% of Greek children had good diet quality and 80% had poor diet quality as measured with the HEI [198].

The mean DQI scores have ranged between 60 and 81% out of a maximum of 100% among European children [200,214–216] with the lowest scores reported in Norway [216] and the highest in a study which included children from several countries (Italy, Cyprus, Germany, Spain, Hungary, Estonia, Sweden and Belgium) [215].

The diet quality, as measured by the adherence to MD, has varied between studies. In Croatia, 6−11% of children had a low adherence to MD and 24−70% a good adherence to MD as measured with the KIDMED index [217,218]. Among Cypriot children, the mean KIDMED score was 9 points out of a maximum of 12 points and majority (79%) of the children showed high adherence to MD with only 1.4% having poor adherence [219]. One third of 3-year-old Norwegian children had high MD adherence as assessed with the fMDS, with the mean fMDS score being 3 points out of the maximum of 6 points [216]. The results were similar to those reported among 2−9-year-old children from 8 European countries [207]; approximately one third or less of the children had high adherence to MD in Italy, Cyprus, Germany, Spain, Hungary, Estonia and Belgium, whereas slightly higher adherence (57%) was found in Swedish children.

As for the other diet quality indices, the mean RC-DQI score among US preschool-aged children was 59 points of the maximum of 90 points, which indicates low diet quality on average [220]. Similar results were found with a modified version of the RC-DQI in Australian children: the mean RC-DQI score was 63 points of the maximum of 85 points [205]. Furthermore, the mean DQI score in Dutch children was 4.6 points out of the maximum of 10 points [201], whereas among Canadian children, the mean DQI-C score was 3.7 points out of the maximum of 6 points [202]. Lastly, among US children, the mean modified DQIS was 22 points out of 45 possible points achieving only half of the maximum score [203].

The consumption of fruits and vegetables of preschool-aged children has mostly ranged from poor to moderate in several studies conducted in Western countries. Among Australian children, only 9% of the children met the recommended amount of 2.5 portions of vegetables per day and 64% met the recommended amount of one serving of fruits per day [205]. In Canadian children, 73% met the recommended amount of four portions of vegetables and fruits per day [202]. Among US children, 6−46% of the children met the recommendation for vegetables and 34−50% for fruits [209,220,221]. Furthermore, 74−77% of US children have been reported to consume fruits and 73−85% consumed vegetables on a given day [212,222]; however, in one study, fried potatoes were the most commonly consumed vegetables [222]. Another study reported that 68% of US children consumed vegetables and 71% consumed fruits daily [221]. Up to 94% of Croatian children consumed fruit or fruit juice daily and 78% consumed vegetables daily; however, only 22% of children consumed vegetables more than once a day [218].

The consumption of milk and other dairy products among preschool-aged also varies between countries and studies according to the literature. Among Canadian children, 38% met the recommendation of at least two portions of milk or alternatives per day [202], whereas in Australia, the proportion of children meeting the recommendation of at least 1.5 portions of dairy per day was somewhat higher

(58%) [205]. In the US, it has been reported that 24−63% of children met the recommended consumption of around two cups of milk and/or dairy products per day [209,220]. Moreover, 70% of US children consumed milk at least two times per day [221]. Another study reported that 81% of US children consumed cow milk and the most commonly consumed type of milk was milk with 2% of fat (30% of children); only 22% consumed low-fat milk or milk 1% of fat [222].

Consumption of grains and whole grains has also been lower than recommended in Western countries in preschool population. In a US study, 57% of children met the recommendation for grains (≥3.0 oz per 1000 kcal) and 24% for whole grains (≥1.5 oz per 1000 kcal) [209], whereas another study found that although 72% of the children met the recommendation for grains, only 8% met the recommendation for whole grains [220]. A third study found that a vast majority of children (95%) consumed grain products on a day of the recall, but less (59%) consumed whole grain products [222]. In Australia, only 11% of 3.5-year-olds met the recommendation for grains (≥4 portions per day) and 20% met that for whole grains (≥2 portions per day) [205]. Similarly, only 13% of Canadian preschool children consumed grain products at least three portions per day as recommended [202].

Also, the consumption of fish needs improvement among preschool-aged children in other Western countries. In Belgium and Croatia, around one third of the sample consumed the recommended amount of fish per week (1−2 times and 2−3 portions, respectively) [218,223]. In Norway, almost half of the children met the recommended amount of 2−3 dinner servings of fish per week [224]. Furthermore, only 7% of US children were reported to consume fish on the day of recall [222]. However, the mean amount of fish consumed among Spanish 4-year-olds was 4 portions per week [225].

To conclude, similar challenges were observed in the preschool-aged children's diet in Finland and in other Western countries indicating that the diet of this age group should be improved globally in order to support the health of the children.

2.3.2.2 Diet in elementary school-aged children

Similar to preschool-aged children, diet quality among elementary school-aged children has been studied with varying methods in Western countries. The diet quality indices include e.g. HEI [104] and its modifications for different purposes and diet cultures such as HEIC-2009 in Canadian children [226] and school-HEI which measures the diet quality during school hours [93]. Other indices used among children include e.g. the Diet Quality Index (DQI) originally developed for adolescents in the US [227], the Diet Quality Index-International (DQI-I) for international comparisons of diet quality [228], Healthy Diet Indicator (HDI) based on WHO guidelines for the prevention of chronic diseases [229], Diet Quality Score

(DQS) based on Irish dietary recommendations [230] as well as the Australian Child and Adolescent Recommended Food Score (ACARFS) that measures the adherence to Australian dietary recommendations [231]. Adherence to MD has been assessed with KIDMED index [206] or the MDS adapted for children [232]. In all the aforementioned indices, a higher score indicates better adherence to the recommended diet. Previous findings on the diet of elementary school-aged children show that, similarly to Finland, the diet quality in Western population is suboptimal with challenges in consuming e.g. vegetables, fruits, fish and grain products according to the dietary recommendations.

In previous studies among 6−13-year-old children in the US, the HEI scores have ranged between 42 and 54 points [94,95,233]. As the HEI scores less than 50 indicate a poor diet quality and scores 50−80 indicate that the diet needs improvement, the literature shows that there is room for improvement in the diet quality in US children. However, the HEI scores have steadily improved from 1999 to 2012 [233]. In Canadian children, the school-HEI score ranged between 54 and 58 points in 6–8 and 9–13-year-old children; thus, the mean diet quality during school hours required improvement [93]. As measured with the HEIC-2009, Canadian children had somewhat higher total scores, namely mean scores of 75 points with one fifth of the children having a good diet quality and three-quarters with a diet quality that needs improvements [226]. In a study with Cretan children, the mean HEI score was 61 points with only 3.5% of the children having good diet quality and 84.5% with a need to improve their diet quality [197].

The total diet quality scores as assessed by the DQI-I ranged from 54 to 59 (out of maximum score of 100) among Italian and US children, respectively [228,234]; only one out of four Italian children had a total DQI-I score higher than 60, which indicates an intermediate/good diet quality [234]. Among British children, the mean DQI score was 9.2 points out of the maximum score of 16 points and the mean HDI score was 4 points out of the maximum of 9 points, children thus reaching less than half of the maximum scores on average [232]. In a study with Australian elementary school-aged children, the mean ACAFRS score was 25 points from a maximum score of 73, indicating that the diet quality was clearly suboptimal [231]. Furthermore, a study conducted in the Netherlands also indicated suboptimal diet quality in 8-year-old children; the mean diet quality score was 4.5 out of a maximum score of 10 [235]. Similarly, in a study with Irish children, the mean DQS score was 9.5 points out of maximum of 25 points [230].

KIDMED scores among 6–16-year-old children living in the Mediterranean area have ranged from 4.4 to 9.7 points out of maximum score of 12 points [138,234,236–239]. One study also reported the mean MDS score of 4.1 out of the maximum score of 8 points among British children [232]. Existing literature indicates a high variance in the adherence to the MD between the studies: 5–78% of children have had a high adherence to the MD, i.e. good diet quality, while moderate diet quality has been reported in 14–69% of the children and poor diet quality in 0.4–33% of the children [138,218,234,237–243]. Furthermore, two studies reported a poor-to-moderate adherence to the MD in 44–74% of the children [242,244].

Regarding the food consumption among elementary school-aged children living in other Western countries than Finland, it has been shown that the consumption of fruits and vegetables has been lower than recommended [93,94,197,234,240,245]. In Sweden, 63% of the children consumed fruits and 55% vegetables on a daily basis [246]. In Croatia, 72% of children consumed vegetables daily and only 21% consumed them more than once per day [218]. Merely 12% of Italian children consumed vegetables more than once a day [240] and another Italian study found that only 2.7% of children consumed at least three portions of vegetables per day and 31% consumed at least two portions of fruits per day [234]. In addition, 16% of Dutch children consumed vegetables and 29% consumed fruits according to the recommendations (150 grams/day of each) [235]. In a Canadian study, 17−18% of the children consumed at least 6 portions of vegetables and/or fruits per day as recommended [245] and similarly in the US, 20% of children consumed at least two portions of fruits per day and 40% consumed at least three portions of vegetables per day as recommended [228]. In other Canadian studies, the adherence to the fruit and vegetable recommendation of at least five portions per day has been somewhat higher with 48−60% of children consuming the recommended amount [247,248]. A good adherence to the recommended fruit consumption was reported among US children [94] and a Spanish study found that 93% of children consumed vegetables more than once a day [138]. Furthermore, 85% of the Croatian children consumed fruit or fruit juice on a daily basis [218] and up to 87% of Portuguese children consumed fruit at least once a day [239].

As for the consumption of milk and dairy products, the consumption is rarely in adherence with the recommendations. Only 9% of Australian children adhered to the guideline of a minimum daily intake of 3.5 portions of the milk, yoghurt and cheese [249]. In the Netherlands, one out of four children consumed dairy products according to the recommended amount of 300 grams per day [235]. In New Zealand, however, up to 72% of the children consumed milk or milk products at least two portions per day as recommended [250]. Furthermore, the type of milk consumed is rarely the recommended one: a study with US children found that only one out of five children of the age group reported low-fat milk as the usual type of milk consumed [251] and another study with Swedish children found that less than half of the children consumed the recommended choice of low-fat milk (1.5% fat) daily [246].

The adherence to the recommended consumption of grain products varies between the studies. In a US study, only 10% of the children consumed at least six portions of grains per day [228], whereas another US study found that 4% of the children consumed whole grain products at least three portions per day [252]. In a more recent Italian study up to 59% of children consumed at least six portions of grains per day [234], and in a Dutch study, 57% of the children consumed whole grains as recommended, i.e. ≥90 g/day [235]. The consumption of whole grains was low among the US children, but the sub scores for refined grains were higher [94]. Although, on average, the consumption of grain products was rather high during school days (2.5 portions) among Canadian children, the consumption of whole grain products was low [93]. Further, studies with Cretan and Australian children reported low sub scores received from the grain consumption [197,231].

Literature shows that also fish should be consumed more regularly among the elementary school-aged children; 24−64% of children have shown to consume fish at least two times a week [138,218,240,253]. For example, one third of Dutch children consumed fish as recommended (≥60 g/week) [235]. In Australia, 57% of children consumed fish at least weekly [249], whereas up to 84% Swedish children consumed fish 1−3 times per week [246]. However, in the UK only less than 5% of children were found to meet the fish recommendation of ≥40 grams of fish per day [254].

In conclusion, similar to the situation in Finland, the diet does not comply with the recommendations in majority of elementary school-aged children living in other Western countries. Thus, the challenges observed in the elementary school-aged children's diet seem to be global.

2.3.2.3 Demographic factors related to child diet quality

The factors associated with children's diet quality have been investigated also in the other Western countries. Children's weight, BMI and adiposity have been linked with diet quality [201,216,230,232,255], although there are also studies reporting no association between these factors [197,209,214,218,240]. In some studies, children's diet quality has been better in younger compared to older children [93–95,203,218], but also opposite results have been found [198,231]. Other studies found no association with the diet quality and age [207,232,236]. Similarly, previous studies have observed that girls have better diet quality than boys [138,211,216,217,231], but here too, opposite results have been found [198,201]. Several studies have also reported no differences in diet quality regarding the child's sex [93,94,197,202,207,214,218,232,236,240,244]. Contrary to the Finnish study, no association between day care attendance and diet quality was detected [201]. Moreover, various studies have found that child's higher physical activity and lower screen time were related to child's better diet quality [197,198,201,216, 217,232,235,236,240,244,255].

In addition to the child factors, also several parental factors have been associated with child's diet quality. Parent's higher education has often been linked with the child's better diet quality [93,197,202,203,207,209,216,232,234,235,240,244,255], but there are also some studies reporting no difference in diet quality based on parental education [197,201]. High household income or socioeconomic status in general have been reported to associate with better diet quality in children [203,207,209,214,235], but some investigators did not find this connection [93,94,201]. In addition, other parental factors including mother's lower BMI [202,255], higher age [255] and a non-smoking status [209,235,255] as well as parent's better health-consciousness [234,244], higher physical activity [234] and healthy eating habits or modelling of healthy eating [205,216] have been associated with a better diet quality in their children. On the contrary, other investigators have found no association between the child's diet quality and parents BMI [201], age [201,202] or the smoking status [201]. Taken together, most of the evidence identifying what factors are related to children's diet quality are contradictory. Thus, more evidence is warranted to clarify the factors linked to child's diet quality and whether diet quality is associated with obesity in children.

2.4 Potential means to support health-promoting lifestyle in pregnant women and children

2.4.1 Health apps in supporting lifestyle changes during pregnancy

Smartphone use has blossomed in the recent years and a majority of people in the developed countries possess a smartphone, e.g. in Finland, approximately 97−100% of 16- to 44-year-olds possess smartphones [256]. As health apps are thus easily available for most women in the child-bearing age in the developed world, they may offer a solution for supporting the adoption of healthy lifestyle habits and allowing self-monitoring during pregnancy [26]. Online interventions can be as efficacious and even more accessible and cost-effective than the traditional interventions [257,258]. For example, in a US study which included personalised gestational weight management intervention for pregnant women with overweight or obesity, the cost of the intervention was 3.5 times less for a participant whose intervention was delivered by the health app, including e.g. self-monitoring features, compared to a participant that received a face-to-face intervention [259]. Similarly, the costs of the health app intervention were 50% less than that of the face-to-face intervention for the health clinic [259]. However, most smartphone-based intervention studies aiming at supporting health-promoting lifestyle in pregnant women have been conducted with a combination of face-to-face visits and a health app [151,259–261].

Previous intervention studies (Table 8) have found that smartphone-based health apps may motivate women in adopting a health-promoting lifestyle during pregnancy. The potential benefits of the interventions delivered by health apps alone or in combination with face-to-face visits include e.g. the prevention of excess gestational weight gain [259,262] and improving dietary habits [151,263,264] and physical activity [151,262]. On the other hand, several studies have also found no effects on these lifestyle measures [260,261,265]. The health apps used in the studies differ in their features and content, and the lifestyle measures, especially the dietary habits and physical activity, have been assessed with varying methods. For example, in some studies the participant's energy and/or nutrient intakes were assessed [151,260], while in others the diet quality scores or dietary risk scores were calculated [260,263–265]. Moreover, the number of participants included in these studies has mostly been rather small (ranging from 27 to 238) [259–263,265,266] and only a few larger studies with 305 to 565 participants have been conducted [151,264,267]. It should be noted as well that several factors may affect the efficacy of the apps, one crucial factor being the adherence to the app usage [268]: if the health app is not being used actively, it cannot exert any effects on the lifestyle habits. One study indicated that participants who used the app had lower glycaemic index and energy intake from free sugars [151], while another reported that higher app usage was associated with higher physical activity levels [262]. However, the app usage patterns within the health app intervention studies have been rarely reported and different approaches have been used in reporting as the usage is largely affected by e.g. the features of the app. Some studies found that the study app was used by 31 to 70% of the participants in the intervention group [151], whereas one study showed that around half of the participants in the intervention group accessed the educational lessons provided in the app and two thirds of the participants recorded their weight in the app on a weekly basis [267]. In addition, one study observed that the median app use time was only 3.8 minutes per week [262], whereas another reported a median app use being 1.7 times per week and median weeks of usage being 18.6 weeks [151].

It is also of note that although there are thousands of health apps available in the app markets globally, the validity of the apps has rarely been evaluated and the health information available in the apps is often not evidence-based [269]. Nevertheless, health apps have become an important source of information for pregnant women [270,271] and in general, pregnant women are eager to gain information on healthy lifestyle [272]. In fact, even simple advice from health care professionals may be effective in the promotion of healthy lifestyle habits [273]. It has been shown that those pregnant women who received professional advice on physical activity during pregnancy were more likely to exercise regularly compared to those who did not receive the advice [177]. Therefore, evidence-based health information delivered via a health app might improve the effects of self-monitoring, but to date there is little scientific evidence to support this speculation.

Before the emergence of smartphones and health apps, some efficacious health technology interventions during pregnancy have been conducted with the intervention delivered by e.g. text messages, e-mails or phone calls [257,274–276]. In these studies, some benefits were reported regarding e.g. lower GWG [257,274,275], better diet quality [276] and maintaining physical activity [274]. In turn, a meta-analysis combining 11 intervention studies utilising the aforementioned health technologies, found no overall effects on the lifestyle habits during pregnancy [277]. However, the development of modern health apps may now provide interventions with e.g. easier self-monitoring features. Thus, this thesis concentrates only on the smartphone-based health app interventions as new approaches for supporting healthful lifestyle habits during pregnancy.

Table 8. Smartphone app-based intervention studies targeted on lifestyle measures, such as dietary habits, physical activity, gestational weight and the incidence of gestational diabetes during pregnancy.

REFERENCE	COUNTRY AND PARTICIPANTS	DESIGN	DATA COLLECTION TIME POINTS	OUTCOMES	DATA ASSESSMENT METHODS	EFFECTS COMPARED TO CONTROL AT FOLLOW-UP
Kennelly et al. 2018 [278] **Ainscough et al. 2020** [151]	Ireland 565 pregnant women with overweight or obesity Intervention group, n=278 Control group, n=287	A 2-arm parallel randomised controlled trial **Intervention:** Nutrition and exercise advice with goal setting provided face-to-face at baseline and follow-up visit, a smartphone app support and fortnightly emails. The app included e.g. a database of low-GI recipes, brief information on physical activity, an exercise of the day, a link to a meal of the day and a tip of the day (motivational quote or pregnancy advice). **Control:** Standard maternity care	- Baseline at 10–18 gw -1^{st} follow-up at 28 gw - 2^{nd} follow-up at 34 gw	- Incidence of GDM (%) - GWG: total (kg) and compared to IOM recommendation (below, within, above) - Dietary intake: Energy (kcal), nutrients (g and E%), glycaemic index, glycaemic load - Physical activity (frequency of 30 min intervals of light, moderate and vigorous leisure time activity per week, MET-mins/week) - Readiness to engage in physical activity behaviours (behavioural stage-of-change: pre-contemplation, contemplation, preparation, action, and maintenance)	- OGTT at the 1^{st} follow-up - Weight measured to assess GWG at baseline and the 2^{nd} follow-up - 3-day food diaries to assess dietary intake at baseline and the 1^{st} follow-up - Questionnaires for physical activity and readiness to engage in physical activity behaviours at baseline and the 1^{st} follow-up	- No effect on the incidence of GDM or GWG - Effects at the 1^{st} follow-up: - ↓ Glycaemic index; energy (kcal), carbohydrates (g), sugars (g), free sugars (g and E%), fat (g and E%), saturated fat (E%), calcium (mg) and sodium (mg) - ↑ Intake of protein (E%) - ↑ MET-mins/wk - ↑ proportion of participants at maintenance stage-of-change for physical activity

REFERENCE	COUNTRY AND PARTICIPANTS	DESIGN	DATA COLLECTION TIME POINTS	OUTCOMES	DATA ASSESSMENT METHODS	EFFECTS COMPARED TO CONTROL AT FOLLOW-UP
Van Dijk et al. 2020 [263]	The Netherlands 218 women <13 weeks pregnant or contemplating pregnancy; 33% pregnant at enrolment Intervention group, n=109 Control group, n=109	A 2-arm parallel randomised controlled trial **Intervention:** A tailored online lifestyle coaching based on identified inadequate intakes of vegetables, fruits, and folic acid supplements with a maximum of three emails or text messages per week; the messages contained seasonal recipes, incentives, feedback, recommendations, and additional questions regarding the diet. **Control:** No coaching, but one seasonal recipe per week to maintain adherence to study.	- Baseline at <13 gw - Follow-up 24 weeks later	- Diet: change in DRS	- Online questionnaires to assess the intakes of vegetables, fruits, and folic acid supplements; DRS calculated from the questions with higher scores indicating unfavourable habits	- ↑ reduction in the DRS - ↑ vegetable intake
Redman et al. 2017 [259]	The USA 54 pregnant women with overweight or obesity Intervention group 1 n=18 Intervention group 2 n=19 Control group, n=17	A 3-arm parallel randomised controlled trial **Intervention 1:** A *SmartMoms* personalized gestational weight management program with behaviour modification counselling (dietary and exercise advice, weight graphs), lessons weekly in 13–24 gw and biweekly from 25 gw until delivery; intervention received in-person	- Baseline at 10–13 gw - Follow-up at 35–36 gw	- GWG: total (kg) and per week according to the IOM recommendation (below, within, above)	- A wireless Internet-connected bathroom scale and a pedometer to self-monitor body weight	- ↓ women exceeding the GWG recommendation in the app group (intervention 2)

REFERENCE	COUNTRY AND PARTICIPANTS	DESIGN	DATA COLLECTION TIME POINTS	OUTCOMES	DATA ASSESSMENT METHODS	EFFECTS COMPARED TO CONTROL AT FOLLOW-UP
		Intervention 2: Same as above, but received via a smartphone app. The app included personalized weight graph and behavioural modification tools including self-monitoring. **Control group:** Usual maternity care				
Yew et al. 2021 [267]	Singapore 340 women with GDM Intervention group, n=170 Control group, n=170	A 2-arm parallel randomised controlled trial **Intervention:** *Habits-GDM* smartphone app with tools for education (12 interactive lessons), easy self-monitoring, timely feedback, chat function, reminder messages and cues to empower patients to make lifestyle changes; a Bluetooth weighing scale provided. **Control:** Standard maternity care; blood glucose values in a paper diary	- Baseline at 12–30 gw - Follow-up until delivery	- GWG: proportion with excess GWG and total GWG (kg)	- Weight at ≤12 gw and the most recent weight before delivery measured at hospital clinic or ward derived from delivery medical records	- No effects on the proportion with excess GWG and the total GWG - ↓ Average glucose readings and proportion of glucose above targets
Dodd et al. 2018 [260]	Australia 162 pregnant women with normal weight,	A multicentre, nested randomised trial **Intervention:** A comprehensive dietary, physical activity, and	- Baseline at 10–20 gw - 1st follow-up at 28 gw - 2nd follow-up at 36 gw	- Dietary habits: HEI scores, intakes of macro-nutrients (g) and food groups (serves/day)	- Dietary habits assessed by semi-quantitative FFQ from which the HEI scores and nutrient and food group	- No effect

REFERENCE	COUNTRY AND PARTICIPANTS	DESIGN	DATA COLLECTION TIME POINTS	OUTCOMES	DATA ASSESSMENT METHODS	EFFECTS COMPARED TO CONTROL AT FOLLOW-UP
	overweight or obesity Intervention group, n=77 Control group, n=85	behavioural intervention with three face-to-face sessions and three telephone calls; goal setting and self-monitoring was encouraged. An additional smartphone app with information on diet and physical activity recommendations and goal setting and self-monitoring features. **Control:** Same intervention as above without the app.		- Physical activity: time spent in e.g. commuting, leisure, household and incidental, and work-related activities (MET-min/wk)	intakes were calculated - Physical activity assessed by the Short Questionnaire to Assess Health-enhancing physical activity (SQUASH)	
Borgen et al. 2019 [266] **Garnweidner-Holme et al. 2020** [265]	Norway 238 pregnant women with GDM Intervention group, n=115 Control group, n=123	A multicentre 2-arm parallel randomised controlled trial **Intervention:** *Pregnant+* smartphone app with goal setting function, possibility for self-monitoring of blood glucose values, automated feedback and information and practical tips regarding GDM, physical activity and diet during pregnancy **Control:** Standard maternity care	- Baseline at <33 gw - 1st Follow-up at 36 gw - 2nd follow-up at 3 months postpartum	- 2-hour blood glucose level of the postpartum OGTT (mean and change, mmol/L) - HDS-P+ and dietary components	- OGTT performed at baseline and 3 months postpartum - FFQ to assess dietary habits at baseline and 1st follow-up. HDS-P+ was calculated from the FFQ.	- No effect

REFERENCE	COUNTRY AND PARTICIPANTS	DESIGN	DATA COLLECTION TIME POINTS	OUTCOMES	DATA ASSESSMENT METHODS	EFFECTS COMPARED TO CONTROL AT FOLLOW-UP
Mackillop et al. 2018 [261]	The UK 203 pregnant women with GDM Intervention group, n=101 Control group, n=102	A 2-arm parallel randomised controlled trial **Intervention:** *GDm-health* smartphone app for recording and self-monitoring blood glucose readings and for bidirectional communication with the clinical team. Text messages containing advice about diet, dose adjustments of hypoglycaemic medications, and messages of encouragement were sent. Clinic visits every 4–8 weeks. **Control:** Standard maternity care; blood glucose values in a paper diary. Clinic visits every 2–4 weeks.	- Baseline at <35 gw - Follow-up until delivery	- Change in glycaemia - Change in HbA1c - Mean blood glucose range - % of 'on target' readings - GWG: total (kg)	- Blood glucose data extracted from either the *GDm-health* app or the paper diaries - Weight measured at each clinic visit	- No effect
Sandborg et al. 2021 [264]	Sweden 305 pregnant women Intervention group, n=152 Control group, n=153	A 2-arm parallel randomised controlled trial **Intervention:** *HealthyMoms* app with information on healthy lifestyle, recipes, exercise guide, push notifications, self-monitoring, goal setting and feedback features for GWG, diet, and physical activity	- Baseline at 14 gw - Follow-up at 37 gw	- GWG: total (kg) - Body fatness (%) - Diet: Swedish Healthy Eating Index score - Physical activity: Time spent in MVPA - Glycaemia - Insulin resistance (HOMA-IR)	- Bod Pod for the assessment of weight and body fatness - 3-day online dietary recall tool (Riksmaten FLEX) for calculating the Swedish Healthy Eating Index score - ActiGraph wGT3x-BT accelerometer for	- ↑ Swedish Healthy Eating Index scores - No effect on GWG, body fatness, MVPA, glycaemia, and insulin resistance - Women with overweight and obesity before pregnancy gained less weight in the intervention group in

REFERENCE	COUNTRY AND PARTICIPANTS	DESIGN	DATA COLLECTION TIME POINTS	OUTCOMES	DATA ASSESSMENT METHODS	EFFECTS COMPARED TO CONTROL AT FOLLOW-UP
		Control: Standard maternity care			assessing physical activity - Blood samples to measure glycaemia and insulin resistance	completers-only analyses
Souza et al. 2022 [262]	Canada 27 pregnant women with normal weight, overweight or obesity Higher app use group, n=14 Lower app use group, n=13	Multi-centre, non-randomised pilot study **Intervention:** *SmartMoms Canada* app with evidence-based information about healthful behaviours during pregnancy, self-monitoring of GWG, sleep and daily steps, and an exercise database. Fitbit® and Withings® apps to be used simultaneously. Participants categorised into two groups based on the median app time use (higher app use ≥3.8 min/wk, lower app use <3.8 min/wk)	-Baseline assessment week at 12–20 gw; - Follow-up assessment week at 24–28 gw; - The 3 apps to be used during the whole study period	- GWG: GWG rate compared to recommendations (below, within, above) - Physical activity: Total daily steps, min/day spent in each physical activity intensity (light, moderate, vigorous), GLTE score. - Dietary intake: Energy (kcal), carbohydrates, fat, fibre and protein (g)	- Withings® Body+ scale for weight assessment at home (≥1 time/wk) - Wrist-worn Fitbit® to track physical activity (7 days at assessment weeks) - Online questionnaire for assessing leisure time exercise (GLTE) - Fitbit® app for recording dietary intake (≥3 days at assessment weeks).	- A trend (moderate effect size) for ↑ adherence to the GWG guidelines in the higher app use group - ↑ MVPA daily average in the higher app use group - No effects on dietary intake

DRS, diet risk score; E%, percent of energy intake; FFQ, food frequency questionnaire; GDM, gestational diabetes mellitus; GLTE, Godin Leisure Time Exercise; gw, gestational weeks; GWG, gestational weight gain; HEI, the Healthy Eating Index; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; HDS-P+, healthy dietary score for Pregnant+; IOM, the Institute of Medicine; MET, metabolic equivalent of task; MVPA, moderate-to-vigorous physical activity; OGTT, oral glucose tolerance test.

2.4.2 Diet quality indices as tools for dietary screening in children

In order to prevent the development of obesity and other lifestyle-related diseases already from the early age, it is essential to identify children in the risk of these health conditions in the clinical practice. As unbalanced diet is one of the main drivers of lifestyle-related health conditions [279,280], it would be useful to measure diet in the screening purposes. Easy-to-use, rapid and validated tools for assessing diet quality in specific age groups could help the health care staff, e.g. child health clinics and school health care, in screening children that are most in need of dietary counselling, and thus possibly enabling the early prevention of obesity and other lifestyle-related diseases.

A variety of diet quality indices have been developed worldwide for assessing diet quality in children, but only few of them have been validated [79]. A valid instrument measures what it is intended to measure and hence, the results are more reliable. Furthermore, the diet quality indices have often been developed for a specific diet culture and food selection and therefore they may not be suitable to be used in all countries and diet cultures. Most of the existing diet quality indices used for assessing diet quality in children, such as the HEI [104], the DQI [200] and the RC-DQI [204], also need a supporting method, such as food diary or FFQ, to be used alongside them for their scoring. Consequently, they are burdensome and time-consuming to use. Furthermore, the scoring of e.g. BSDS is based on calculating the population quantiles of the consumption of each score component [96], and thus the score cannot be calculated for individuals e.g. in health care. Therefore, this kind of indices are often suitable for research purposes only.

Stand-alone tools, which can be completed and scored independently, i.e. without an additional dietary assessment method, ensure rapid and easy measurement of diet quality and screening in situations with limited time resources, namely in the clinical practice. However, only few stand-alone tools have been developed for assessing diet quality in children (Table 9). In Australia, validated stand-alone diet quality indices have been developed for 2–5-year-old (ARFS-P) [281] and 9–12-year-old children (ACARFS) [231]. Spanish KIDMED index, developed for 2–24-year-old children and adolescents, is based on MD and could possibly be used in other countries especially in the Mediterranean region [206]. Lastly, a stand-alone tool for assessing the diet quality has been developed for 2−6-year-old (preschool-aged) children in Finland [282]. However, there is no stand-alone tool available for assessing diet quality in school-aged children in Finland. An index validated for small children might not be valid for older children because, with age, children’s dietary choices may change, e.g. the consumption of gruel and porridge may be lower and the consumption of fast food, sugary beverages and sweets may be higher in school-age compared to preschool-age. Hence, an index that takes into account the typical foods consumed by the age group is likely to be more valid tool for dietary assessment and screening of children in the risk of obesity and other lifestyle-related diseases.

Table 9. Children's stand-alone diet quality indices developed globally.

REFERENCE	**Serra-Majem et al. 2004** [206]	**Marshall et al. 2012** [231]	**Burrows et al. 2014** [281]	**Röytiö et al. 2015** [282]
Diet quality index	KIDMED	ACARFS	ARFS-P	CIDQ
Country	Spain	Australia	Australia	Finland
Target age (years)	2–24	9–12	2–5	2–6
Number of participants	3 850	691	142	400
Type of index	16 questions	70 questions (chosen from FFQ)	70 questions (chosen from FFQ)	15 questions (drawn from FFQ based on statistical analyses)
Scoring	0–12; categorisation in three groups	0–73; categorisation by quartiles	0–73; categorisation by quartiles	0–21; categorisation in three groups based on statistical analyses
Basis of scoring	Mediterranean diet	Australian Dietary Guidelines for Children and Adolescents 2003	Australian Dietary Guidelines 2013	Nordic Nutrition Recommendations (2006; 2012)
Diet components evaluated within the index	Breakfast, fast food, vegetables, fruits, grain products, dairy, legumes, fish, olive oil, sweets	Vegetables, fruits, meat, non-meat protein sources, grain products, dairy, water, spread/sauce	Vegetables, fruits, meat, non-meat protein sources, grain products, dairy, water, spread/sauce	Whole grain products, vegetables, fruits, berries, fibre, quality of fat, sucrose, calcium

ACARFS, the Australian Child and Adolescent Recommended Food Score; ARFS-P, the Australian Recommended Food Scores for Pre-schoolers; CIDQ, the Children's Index of Diet Quality; FFQ, food frequency questionnaire; KIDMED, the Mediterranean Diet Quality Index for children and adolescents.

2.5 Summary of the literature

Unfavourable lifestyle habits, including poor quality diet and low physical activity, may in time lead to obesity, which further is a risk factor for several lifestyle-related diseases, such as type 2 diabetes and cardiovascular diseases. The high prevalence of obesity in all age groups is a major public health concern globally and Finland is not an exception. Previous literature shows that there is room for improvement in the lifestyle habits of both pregnant women and children in Finland. In pregnant women, the diet quality and consumption of foods relevant for health, e.g. vegetables, fruits, whole grain, soft fat and fish, has been suboptimal. In addition, the consumption of vitamin D and folic acid as food supplements has been lower than recommended, but the existing data are inconclusive and information on daily intake of food supplements and adherence to the recommended and safe doses is scarce. Physical activity level has also been lower than recommended, whereas the gestational weight gain is exceeding the recommended level in a large proportion of pregnant women. It is noteworthy that diet quality and food consumption have not been widely studied among preschool-aged and elementary school-aged children in Finland, but the existing literature shows that children have similar challenges in their diet as Finnish adults. Adopting health-promoting lifestyle habits already at an early age has a major impact on the health in both short and long term as lifestyle habits adopted in childhood often remain in the adulthood. Therefore, new solutions for supporting the health-promoting lifestyle habits are needed. The literature suggests that health apps might be beneficial in supporting the health-promoting lifestyle habits in pregnant women, but the evidence is somewhat inconclusive and studies with larger study populations are needed. Moreover, stand-alone diet quality indices might serve as new tools for screening of children most in need of dietary counselling. However, low-burden indices that are suitable for Finnish food culture are not available for all age groups, e.g. elementary school-aged children, in Finland.

2.6 Hypotheses of the study

The hypotheses of this thesis are that lifestyle habits of Finnish pregnant women and dietary habits of Finnish children are currently suboptimal as compared to the recommendations. The diet is less healthy in children with overweight/obesity and in those children whose parents have less healthy lifestyle habits. Use of a health app combined with provision of evidence-based information regarding health-promoting lifestyle supports recommended weight gain, consuming a high-quality diet and maintaining physical activity in pregnant women. A short set of questions chosen from a larger set of FFQ questions describes the quality of an overall diet as defined in the dietary recommendations.

3 Aims

The overall aims of this thesis were to assess lifestyle habits of pregnant women and children with reference to the respective recommendations as well as to study and develop novel means for dietary screening and health promotion in these target groups.

The specific aims were to:

1) assess lifestyle habits, including diet, physical activity and gestational weight gain, with reference to the recommendations in a pregnant women population in a longitudinal setting (study I) and diet quality components and physical activity in another sample of pregnant women (study II), and further to investigate food supplement consumption and adherence to food supplement recommendations during pregnancy (study II)

2) investigate the efficacy of a health app as a tool for improving lifestyle habits during pregnancy (study I)

3) study diet and its association with overweight status and demographic factors in preschool-aged (study III) and elementary school-aged children (study IV)

4) develop a valid tool for screening purposes: a short method for the assessment of diet quality in elementary school-aged children (study IV)

4 Materials and Methods

4.1 Study design, recruitment and subjects

This thesis is based on four independent studies investigating lifestyle habits and efficacy of a health app on improving the lifestyle habits in a pregnant women population (study I), supplement use during pregnancy in four European countries (study II), diet and associated demographic factors in preschool-aged children (study III) and elementary school-aged children (study IV) as well as the development of a diet quality index for elementary school-aged children (study IV). Details on the study designs, data collection and study populations of these studies are summarised in Figure 3.

PREGNANT WOMEN

Study I

Prospective online study with a randomised controlled pilot intervention
- 1038 pregnant women across Finland
- Data collected with online questionnaires and a health app; June 2017−August 2018
- Intervention: Healthy lifestyle tips sent weekly via the health app
- Follow-up and app use from early pregnancy (<28 gw) to delivery
- Assessment of gestational weight, diet quality and physical activity in early and late pregnancy (33-40 gw)

Study II

Cross-sectional survey
- 1804 pregnant women at any stage of pregnancy from Finland, Italy, Poland and the United Kingdom
- Data collected with online questionnaires; July 2018−June 2019
- Assessment of food supplement consumption and awareness of food supplement recommendations during pregnancy

CHILDREN

Study III

Cross-sectional study
- 766 preschool-aged (2−6-year-old) children and their parents from across Finland
- Data collected during child health clinic visit by nurses;
- February−June 2016
- Assessment of diet quality, food consumption and anthropometric data

Study IV

Cross-sectional study
- 266 elementary school-aged (7−12-year-old) children and their parents living in Southwest or Eastern Finland (Turku or Kuopio area)
- Data collected by online questionnaires and in a study visit; March 2017−February 2018
- Assessment of dietary intake, food consumption and anthropometric data

Figure 3. Summary of the study design, data collection and study populations in the studies I-IV.

4.1.1 Health app study

In the health app study (study I), pregnant women from across Finland were recruited in prospective online study including a pilot intervention. The study had three purposes: 1) to characterise app use and users among pregnant women, 2) to investigate effects of app using frequency on the change in lifestyle habits during pregnancy and 3) to study in a 2-arm randomised controlled pilot intervention trial whether the addition of evidence-based information on health-promoting lifestyle delivered via the health app would have an effect on the change in lifestyle habits during pregnancy. The study was descriptive and a pilot study regarding the intervention part. Social media was used as a recruitment channel and a large sample size (n=1000) compared to previous studies investigating health technology during pregnancy (*n* typically 10−238) [257,260,261,263,266,274–276,283] was sought for exploratory purposes. Women with pregnancy weeks less than 28 and fluent in Finnish were invited to the study. An online questionnaire was sent to the eligible women in early pregnancy (gestational weeks 4–27) and the second questionnaire was completed in late pregnancy (gestational weeks 33–40). The questionnaires inquired about e.g. lifestyle factors (weight, diet quality and physical activity) and sociodemographic information (only in early pregnancy).

After completing the early pregnancy questionnaire, participants were sent a web link to download one of two health apps that delivered the intervention. The women were randomised into two groups: women were asked to use, until delivery, either a standard version of the health app (standard app group) or an enhanced version (enhanced app group). Randomisation was conducted using an online random number generator, with a block size of 6, arranged in the order of contacting the researchers. Researchers sent non-personalised information on the health-promoting lifestyle during pregnancy, i.e. tips on health-promoting eating habits, exercise, appropriate gestational weight gain and risks of gestational diabetes, through the app only to the enhanced app group on a weekly basis. Examples of the tips are shown in Supplementary Table 1. All the information was based on national recommendations regarding diet, physical activity and weight gain during pregnancy [28,29,58]. The tips were designed by the research team to inform the participants about the benefits of a healthy lifestyle and the potential risks related to an unhealthy lifestyle, e.g. the risk of gestational diabetes. The tips were expected to motivate the participants to obtain health-promoting lifestyle habits during pregnancy. Both apps could be used for self-monitoring, i.e. recording lifestyle habits, including weight, diet and physical activity during pregnancy.

The health app (Dottli, Dottli Oy) is a commercial app originally developed for supporting the self-care of diabetes. For the purposes of this research, minor modifications were made to the app, i.e. features allowing the participant to record e.g. their daily fruit and vegetable intakes were added and participants were prevented from hiding their recordings from the researchers. The app was chosen for the study as it was anticipated that an app developed for supporting the self-care of diabetes could also be used to support self-care of GDM and health-promoting lifestyle habits of pregnant women in general.

Participants were asked to record their lifestyle information in the health app regularly from the baseline until delivery. Several recording types were available in the app, e.g. weight (in kilograms), number of fruit and vegetable portions consumed daily, type of meals eaten in a day (breakfast, lunch, snack, dinner and evening snack), mood (excellent, good, ok, bad and horrible) and the time, type (e.g. walking, cycling, gym) and intensity (light, moderate, vigorous) of physical activity. The recording types with their options were listed in the app and the participant could choose themselves which ones they wanted to record. No limitations were given on how many recordings per day the participant could make. If the participant had a physical activity tracker compatible with the app, they were encouraged to link them to transfer the physical activity data to the app. Self-monitoring the potential changes in the lifestyle habits was possible by viewing graphs of the recordings in the app. Both intervention groups received weekly notifications via the app that motivated them to make recordings regularly.

4.1.2 Food supplement survey

In the food supplement survey study (study II), data on knowledge and use of food supplements (including vitamin and mineral products and excluding herbal products) was collected with a cross-sectional design using an online questionnaire in Finland, Italy, Poland, and the UK. The four countries were chosen for the study due to their diverse geographical and socioeconomic characteristics and different business environments within food supplement markets. The desired number of participants was 500 from each country, i.e. altogether 2000 participants, which is comparable to previous studies reporting food supplement use during pregnancy [154,156,157]. Pregnant women, aged 18 to 45 years, at any stage of pregnancy able to complete the questionnaire in the main language in each country (i.e. Finnish, Italian, Polish or English) were invited in the study.

The questionnaire was developed in English and translated into each language by the research team. To ensure the quality and uniformity of the translations, the questions were translated back to English and modifications were made in the Finnish, Italian and Polish versions of the questionnaire if necessary.

To test the questionnaires and the feasibility of the recruitment method, two pilot studies were conducted in each country prior to the recruitment. In the first pilot study, pregnant or recently delivered women (n=19 altogether) completed the questionnaire and gave feedback to the researchers on e.g. the clarity of the questions. In the second pilot study, the questionnaire was distributed via social media to the target group and electronic feedback on the questionnaire was gathered (n=91 altogether). Based on the feedback from the pilot studies, the questionnaire was improved by clarifying some questions and providing more response options to others.

Recruitment was carried out by distributing a web link to the questionnaire via social media. In the UK, also other channels, such as childbirth charity research web pages and leisure activity centres, were used in the recruitment.

4.1.3 Preschool-aged children's diet quality study

In the preschool-aged children's diet quality study (study III), the data were collected with a cross-sectional design in Finnish child health clinics nationwide. A representative sample of 1000 preschool-aged (2- to 6-year-old) children across Finland was aimed to be gathered, i.e. a similar number of cases as in previous studies examining children's diet [284,285]. The target group comprised of 2- to 6-year-old children attending a child health clinic with their parent. Children with chronic and food-related diseases such as celiac disease, multiple food allergies, single food allergies that would significantly influence dietary intake e.g. milk allergy, and children with other special diets were excluded. Nurses in each health clinic were asked to invite 15 parents with their children to participate: three children from each of the following age groups: 2-, 3-, 4-, 5-, and 6-year-olds. In total, 118 health clinics from 118 towns from all 20 hospital districts in mainland Finland were invited to participate in the study. The largest towns in each health district were included by default and a random number generator was used to choose three other towns per district to be invited in the study. Towns with at least 300 preschool-aged children were considered eligible to ensure a sufficient number of families attending clinic visits throughout the recruitment period.

4.1.4 Diet quality index development study

With a cross-sectional study design, a diet quality index for elementary school-aged (7- to 12-year-old) children was developed (study IV) by considering their food consumption assessed by a FFQ and nutrient intakes calculated from a five-day food diary. Elementary school-aged children living in the Turku area (Southwest Finland), or the Kuopio area (Eastern Finland) were invited to take part in the study. We aimed for a sample of 420 children (70 per school grade) i.e. a similar number of cases as in a previous diet quality index validation study [282]. Recruitment was primarily carried out by sending invitation letters to a random sample of 5000 families (name and address of the child and a parent drawn from the Finnish Population Information system) with children from the target age groups living in Turku or Kuopio or in neighbouring towns. Invitation letters were also sent through an electronic system used in home–school communication and e-mailed to children's hobby organisations. Children and/or parents with inadequate Finnish language skills to complete the questionnaires or those otherwise unable to give their informed consent, children with severe diseases, such as cancer, and children with special diets or food allergies significantly impacting their dietary intake (e.g. gluten-free diet, milk allergy or multiple food allergies) were excluded from the study. If there were more than one eligible child in a family, only one child was included in the study; the choice was made by the family.

4.2 Measurements

4.2.1 Dietary assessment

4.2.1.1 Diet quality and dietary intake

In the study I, pregnant women's diet quality was assessed by the validated IDQ as an online questionnaire. The index is a stand-alone tool which measures the overall adherence to Finnish dietary recommendations [31]. The index includes 18 questions inquiring about the frequency and amount of consumption of food items, such as vegetables, fruits and berries, whole-grain, fish, spreads, dairy and sugar-rich foods, over the preceding week [31]. The IDQ scores range from 0 to 15 points with scores ≥10 points indicating good diet quality as defined in the development and validation study [31]. The IDQ score was not calculated for an individual in case of three or more missing answers. In the validation study, the index had a sensitivity of 0.67 and a specificity of 0.71 to identify those with good diet quality in the receiver operating characteristics (ROC) curve analysis [31]. Diet quality components (Table 10), chosen from the IDQ questions, were also compared with Nordic and Finnish dietary recommendations [28,33].

In the study II, the dietary habits during pregnancy were briefly inquired by an online questionnaire consisting of questions regarding the frequency of consuming selected diet quality components (Table 10).

In the study III, child's diet quality was assessed by a validated diet quality index, the CIDQ, filled in by the parent in the child health clinic. The CIDQ is a stand-alone tool to measure the overall adherence to the Finnish and Nordic dietary recommendations given for children aged 2 to 6 years old [282]. The index consists of 15 questions inquiring about the frequency and amount of consumption of food items relevant for children, including vegetables, fruits and berries, porridge, spread, vegetable oil, cheese, milk, and sugary yoghurts and juices over the preceding week [282]. The CIDQ scores range from 0 to 21 points, and based on the total scores, diet quality was categorised into 3 groups: poor (<10 points), moderate (10−13.5 points), and good (14−21 points) as defined in the original study reporting the development and validation of the index [282]. The index got sensitivity values of 0.59−0.77 and specificity values of 0.69−0.82 in the ROC analysis, and the area under the ROC curve was 0.79 and 0.75 for at least moderate and good diet quality, respectively, which is considered acceptable [282,286]. Adherence to dietary recommendations was further evaluated by comparing the consumption of diet quality components (Table 10), chosen from the CIDQ questions, to the respective dietary recommendations. The feasibility of the CIDQ in child health care practice, inquired with a questionnaire from nurses, was considered acceptable particularly on the point of view of dietary counselling as the majority of nurses considered that the index helped them to start a nutrition conversation with the families and that it was easy to give feedback to families based on the index, although based on the results, further training on the use of the index or automatised scoring calculation system would be desirable (Supplementary Figure 1).

In the study IV, children's dietary intakes were assessed by a five-day food diary and a FFQ specifically designed for the purpose of the index development. The food diaries were filled in by the children with the help of their parents prior to the study visit. Food diary was asked to be filled in for five consecutive days with at least one weekend day. Families were instructed on how to fill in the food diary accurately and portion picture booklets [287] were provided to help them to estimate the portion sizes of consumed foods and drinks. Researchers checked the food diaries for completeness and accuracy during the study visits. Moreover, information on the school lunch menu and typical foods served were inquired from the school meal providers. Food intake calculation software Micro-Nutrica version 2.5 (Research Centre of the Social Insurance Institution, Turku, Finland), which uses Finnish and international data on the nutrient compositions of food items [288], was used to calculate the daily intakes of nutrients and food groups from the food diaries. The software is regularly updated by clinical nutritionists of PANIC study group (University of Eastern Finland, Kuopio, Finland) by adding new food items and products with their exact nutritional contents obtained from the producers. Also, major changes in food compositions over the years, e.g. the vitamin D fortification of milk products and fat spreads, have been taken into account when updating the software. To identify dietary patterns, 21 food groups (Supplementary Table 2) were created by combining nutritionally similar food groups. Principal component analysis was used to reduce the food groups into a smaller number of components according to Pajunen and colleagues [35]. Based on the loadings of different food group variables, two components, which explained the total variance in the data the most, were translated into dietary patterns (analyses by courtesy of MSc Lotta Saros, Institute of Biomedicine, University of Turku, Finland). From the analyses, each participant received factor coefficient scores indicating their adherence to the two patterns. Based on the scores, the participants were divided into two groups: adhering to the 'Healthier pattern' (higher score for the pattern representing healthier diet) or the 'Unhealthier pattern' (higher score for the pattern representing unhealthier diet). Furthermore, the FFQ consisting of 29 multiple-item questions on the consumption of food items, portion sizes and eating frequency over the previous week was filled in during the study visit by the children and parents together. The questions reflected the typical foods consumed by the age group as well as the health-promoting dietary choices set in the Finnish and Nordic nutrition recommendations [28,33]. Adherence to dietary recommendations was evaluated by comparing the consumption of selected diet quality components (Table 10) to the respective dietary recommendations.

Table 10. The selected diet quality components reported in each study.

CONSUMPTION OF THE SELECTED DIET QUALITY COMPONENTS (YES/NO)	STUDY I	STUDY II	STUDY III	STUDY IV
Vegetables daily	x	x[a]	x	x
Fruits and/or berries daily	x	x	x	x
Vegetables, fruits and/or berries ≥5 portions/day	x	-	x	x
Whole-grain products daily	x	x	-	-
Fish ≥2 times a week	x	x[b]	-	x
Fat-free milk/sour milk	x	-	x	x
Vegetable oil-based spread (with 60−80% of fat) on bread	x	-	x	x
Having a regular eating frequency	x[c]	-	-	x[d]

Study I: Lifestyle habits and health app use in pregnant women. Study II: Food supplement use in pregnant women. Study III: Diet quality in preschool-aged children. Study IV: Development of diet quality index for elementary school-aged children. [a] In the study II, the consumption of vegetables ≥2 times a day was reported. [b] In the study II, the consumption of fish ≥1 times per week was reported. [c] Skipping ≤2 lunches or dinners per week. [d] Eating at 3−4-hour intervals.

4.2.1.2 Food supplements

In the study II, detailed information on the type and dose of the food supplements used as well as the frequency and duration of supplement use during pregnancy was collected. Participants were asked to upload pictures of the supplement packages or web links of the actual products used in order to calculate the daily intake of each nutrient from the supplements as accurate as possible. The daily intake of supplements was compared with the supplement recommendations in each country (Table 11) and the safe upper intake levels of supplements when available as set by the European Food Safety Authority [289].

Table 11. Nutrients that are recommended to be used as supplements during pregnancy and their doses in each of the studied country.

RECOMMENDED SUPPLEMENTS AND THEIR DOSES*	FINLAND	ITALY	POLAND	THE UK
Folic acid (µg)	400**	400**	400	400**
Vitamin D (µg)	10	-	50	10
Iodine (µg)	-	-	200	-

*Other micronutrients, such as iron, calcium and magnesium, are recommended to be used as food supplements only for pregnant women at risk of deficient intakes. **Until the 12th pregnancy week.

4.2.2 Physical activity

In the studies I and II, physical activity was assessed using a validated questionnaire with three multiple-choice questions on the intensity, frequency and duration of leisure-time physical activity during the preceding week [290]. Each answer was scored, and the total index score was calculated as intensity × frequency × duration of activity, the score range being 0−105 MET h/wk [290]. All three questions had to be answered for the index score to be calculated. The index scores were categorised as follows: <5 MET h/wk (light activity), 5−30 MET h/wk (moderate activity) and >30 MET h/wk (vigorous activity). Level 5 MET h/wk indicates one hour of moderate-intensity physical activity in a week, whereas level 30 MET h/wk denotes one hour of moderate-intensity physical activity in a day [290].

4.2.3 Anthropometric data

In the studies I and II, participants reported their pre-pregnancy weight, current weight and height. Gestational weight gain was calculated as the difference in self-reported weight between late pregnancy (weeks 33−40) and pre-pregnancy. When investigating the intervention effect (study I), the GWG was calculated as the difference in self-reported weight between late pregnancy (weeks 33−40) and early pregnancy (baseline). In both studies, the pre-pregnancy BMI was calculated and categorised to underweight, normal weight, overweight and obesity as per the World Health Organization guidelines [189].

In the study III, nurses measured children's weights and heights in the child health clinic, whereas in the study IV, the children's weights and height were measured by the researchers during a study visit. In Eastern Finland, children's heights and weights were measured with an electronic measuring station (Seca inspecta 285, Seca, Germany). In Southwest Finland, the height was measured with a wall-mounted stadiometer (Person-check, Medizintechnik KaWe, Kirchner & Wilhelm, Germany) and weight with an electronic scale (the BOD POD system, COSMED, Inc., Concord, CA, USA). In both studies, standing heights were measured to the nearest 0.1 cm and standing weights to the nearest 0.1 kg.

The weight status of the children was defined by using BMI standard deviation score (BMI SDS) based on the Finnish growth reference curves and categorised as underweight (BMI SDS ≤−1.6482 for girls and ≤−1.8344 for boys), normal weight (BMI SDS −1.6481 to 1.1628 for girls and −1.8343 to 0.7783 for boys), overweight (BMI SDS 1.1629 to 2.1064 for girls and 0.7784 to 1.7015 for boys) and obesity (BMI SDS ≥2.1065 for girls and ≥1.7016 for boys) [291].

4.2.4 Other questionnaire data

In the studies I and II, participants filled in structured questionnaires inquiring about background factors, including stage of pregnancy in weeks, age, marital status, parity, education, whether working in the health sector (study II), place of residence (study I), smoking habits and alcohol consumption (study II) either in the early pregnancy questionnaire (study I) or at any stage of pregnancy (study II).

In the studies III and IV, the parents filled in self-administered questionnaires (paper and pencil -based in study III, online in study IV) concerning child (sex and age; study III) and parental demographic information (age, education, if the parent held a degree in the field of health or nutrition (study III), work position, household income, smoking habits as well as self-perceived level of physical activity and healthiness of diet (study III)). Self-reported weight and height was collected from the parents. Parental BMI was calculated and categorised according to the classification by the WHO (underweight, normal weight, overweight and obesity) [189].

4.3 Statistical analyses

Summary of the explanatory and outcome variables and the statistical methods used in the studies I−IV are shown in Table 12. The development process of the diet quality index (study IV) has been depicted in detail later in this chapter.

Differences in lifestyle habits between early and late pregnancy in all participants (study I) were included only in this thesis to assess the changes in lifestyle habits over the course of pregnancy regardless of the intervention. For these analyses, Wilcoxon signed rank test was used for non-parametric data and McNemar test and Stuart-Maxwell test for categorical data as appropriate. Also analyses regarding dietary patterns in elementary school-aged children (study III) were only presented here; the relationship between the child's adherence to the dietary patterns and child and parental demographic factors (such as child's age and sex, mother's and father's age, weight status, education and smoking habits) were studied with Chi squared and Fisher's exact tests in the preliminary analyses. To further analyse the associations between child's adherence to the dietary patterns and the chosen demographic factors

(P-value<0.05 in the preliminary analyses; child's sex, area of living, parents' age, education and father's smoking habits) were examined using multivariable logistic regression analyses (separate models for maternal and paternal factors with child factors).

All tests were 2-tailed and statistical significance was set at P-value <0.05. Analyses were performed using both IBM SPSS statistics version 27.0 for Windows (IBM SPSS Inc. USA, Chicago, IL, USA) and SAS software version 9.4 (SAS Institute Inc., Cary, NC; studies I, II and IV) or with IBM SPSS statistics version 25.0 for Windows (IBM SPSS Inc. USA, Chicago, IL, USA; study III)

Table 12. Summary of the explanatory and outcome variables and the statistical analyses used in each study.

STUDY	EXPLANATORY VARIABLES	OUTCOME VARIABLES	STATISTICAL TESTS
I	• Enhanced and standard app users • Frequent, occasional and app non-users	• Lifestyle habits (diet quality, physical activity, weight gain) in early and late pregnancy, changes between the time points	• Independent samples T-test and ANOVA with Tukey method (parametric data) • Mann-Whitney U test and Kruskal-Wallis test (non-parametric data) • Fisher's exact test, Chi-square test and logistic mixed model for repeated measures (categorical data) • Linear mixed model for IDQ scores (potential confounding factors: mother's age, parity, marital status, education and pre-pregnancy BMI)
II	• Differences between four countries • Demographic and behavioural factors	• Daily intakes of nutrients from food supplements and adherence to recommendations • Proportions of women using food supplements during pregnancy	• Kruskal-Wallis test with Bonferroni correction (non-parametric data) • Chi-square test with Bonferroni correction (categorical data) • Logistic regression analysis (univariate approach with addition of country)
III	• Children with underweight/normal weight and overweight/obesity • Child and parental demographic factors	• Diet quality	• ANOVA with Tukey method (parametric data) • Chi-squared test (categorical data) • Linear mixed model analysis; town of living included as a random effect* (complete case analysis)
IV	• Intakes of energy and nutrients • Child demographic factors	• Diet quality scores and/or categories (children with good or poor diet quality)	• Independent samples T-test, ANOVA with Tukey method and Pearson correlation coefficient (parametric data) • Mann-Whitney U test and Spearman correlation coefficient (non-parametric data) • Fisher's exact test and Chi-squared test (categorical data)

Study I: Lifestyle habits and health app use in pregnant women. Study II: Food supplement use in pregnant women. Study III: Diet quality in preschool-aged children. Study IV: Development of diet quality index for elementary school-aged children. ANOVA, One-way analysis of variance. *Town of living was included as a random effect in the model to take into account that all age groups of the 2−6-year-old children were not represented within the participating towns as e.g. there were less children attending child health clinics during the study period in some of the towns.

Diet quality index development process

The steps of the diet quality index development process (study IV) were as follows:

1. **Choosing the criteria for a health-promoting diet:** Ten criteria of a health-promoting diet (the daily intakes of SFA (E%), sucrose (E%), fibre (g/MJ), vegetables, fruits and berries (g), vitamin C (mg), zinc (mg), calcium (mg), folic acid (µg), vitamin D (µg) and iron (mg) in accordance to those recommended) were chosen based on Finnish and Nordic nutrition recommendations [29,33] for the target age group. The key nutrients for children's healthy diet were chosen as the criteria, and since the role of vegetables, fruits and berries in a healthy diet is undisputed, the intake of these food items was also included in the criteria list. The intakes of the nutrients and foods were calculated from the food diaries and the children's adherence to the recommendations were assessed. Pearson and Spearman correlations were analysed between the intakes of the ten nutrients and foods with each other, and three criteria (folic acid, vitamin D and iron) with correlations with the other nutrients or foods (r=0.52–0.79) were excluded from the criteria list. Thus, seven criteria (Table 13) were included in the analyses.

Table 13. Criteria for health-promoting diet based on Finnish and Nordic nutrition recommendations for 6–9- and 10–13-year-old children [29]. Modified from Publication IV.

CRITERIA FOR HEALTH-PROMOTING DIET	RECOMMENDATION FOR 6–9 Y CHILDREN	RECOMMENDATION FOR 10–13 Y CHILDREN
Sucrose	<10 E%	<10 E%
Saturated fatty acids	<10 E%	<10 E%
Dietary fibre	2–3 g/MJ (15–20 g/d)	≥ 3 g/MJ (25–35 g/d)
Vitamin C	≥ 40 mg/d	≥ 50 mg/d
Calcium	≥ 700 mg/d	≥ 900 mg/d
Zinc	≥ 7 mg/d	≥ 8/11 mg/d (girls/boys)
Vegetables, fruits and berries	≥ 250 g/d	≥ 250 g/d

E%, percent of energy intake. MJ, megajoule.

2. **Forming the model:** Spearman correlation coefficients were used to investigate the associations between the number of fulfilled health-promoting diet criteria (continuous outcome) and categorised ordinal FFQ variables inquiring about the frequency of consumed food items. Combination variables, such as 'portions of vegetables, fruits and/or berries consumed per day' were used in the analyses e.g. if combining similar food items would be advantageous in the analyses. FFQ variables were categorised based on the distribution of frequencies in the study population and/or the extent to which they fulfilled the dietary recommendations, e.g. the portions of vegetables, fruits and/or berries consumed

per day was categorised as follows: 0–1.9, 2–4.9 and ≥5 portions a day, the last category representing the recommended consumption. All the categorised ordinal variables, inquiring about the frequency of consumed food items, with significant correlations with the number of fulfilled health-promoting diet criteria (continuous outcome) were chosen for further analyses. Despite non-significant correlations with the criteria, some variables were deemed important when measuring a child's diet quality and were consequently included in the next step. By using descriptive statistics, categorised ordinal FFQ variables inquiring about the frequency and portion sizes of consumed food items (now treated as categorical variables) as well as nominal variables (e.g. inquiring about the type of milk consumed by fat percent) were chosen for stepwise logistic regression analysis. For the analysis, the continuous variable on the number of fulfilled health-promoting diet criteria was categorised into three categories as forming a three-category index was considered desirable. Based on the stepwise logistic regression analysis, FFQ variables with any association with the health-promoting diet criteria (P-value≤0.3, 12 variables) and variables potentially important for diet quality based on scientific literature, i.e. the number of days per week consuming berries, porridge and/or whole grain cereal, nuts, fish and sugary beverages, the portions of vegetables, fruits and/or berries consumed per day and whether the eating habits differed between weekdays and weekends (altogether 7 variables), were included in the next step.

3. **The modelling phase:** Univariable multinomial logistic regression analyses were employed to identify the final index questions from the FFQ which best represented the diet quality of the children. At this point, various categorisations for the health-promoting diet criteria were tested and for statistical reasons, the subsequent classification was chosen for further investigation: poor (0–2 criteria fulfilled), moderate (3–5 criteria fulfilled) and good diet quality (6–7 criteria fulfilled).
4. **Forming the scoring method:** The response options of FFQ questions were scored (0, 0.5, 1 or 2 points) based on the parameter estimates of the logistic regression models and the degree of fulfilling the dietary recommendations. The total index scores ranged from 0 to 16.5 points (highest scores reflected a better diet quality). Majority (70%) of the index questions had to be answered and missing answers were replaced with the mean of all the other answers.
5. **Assessing validity and defining the cut-off value:** To assess the sensitivity, specificity and accuracy of the index in separating children based on the diet quality scores, ROC curves were applied [292–294]. The ROC analysis was used to choose the suitable cut-off point for a good diet quality. Sensitivity and specificity were considered equally important, and the optimal cut-off point was

defined as a value nearest to the upper left corner (minimising the Euclidean distance). According to the statistical experiments, the index scores were divided into two categories named as 'poor' (0–2 criteria fulfilled) and 'good' diet quality (3–7 criteria fulfilled). The names of the categories were chosen for simplicity to depict diet that is either farther from or closer to the recommended diet as measured with the selected criteria.

4.4 Ethical approval and consent

All studies received a favourable ethical opinion from the Ethics Committee of the University of Turku, Turku, Finland, and the studies were conducted in accordance with the Declaration of Helsinki and its later amendments. Before participation, informed consent was gathered electronically from all pregnant women (studies I and II). Study I was registered in Clinical Trials.gov (registration number NCT05094479). In study III, each child health clinic's consent to participate in the study was obtained from the person in charge and all parents provided written informed consent for themselves and on behalf of the children. In study IV, all parents and children provided written informed consent prior to participation.

5 Results

5.1 Characteristics of the study subjects

Characteristics of the pregnant women are presented in Table 14. Of the pregnant women in the study I, 44% were living in the Southern Finland, 39% in the Western Finland, 7% in the Eastern Finland and 11% in the Northern Finland. In the study II, 30% (536/1804) of the participants were from Finland, 33% (591/1804) from Italy, 31% (556/1804) from Poland, and 7% (121/1804) from the UK. The median (Q1−Q3) gestational weeks of the pregnant women were 14.4 (9.6–20.1) in early and 36.0 (35.5−36.6) in late pregnancy in the study I and 24.7 (16.7–32.4) at the time of participating in the study II. The pregnant women in both studies I and II were overall highly educated with a college or university level degree and majority were primiparous. In the study I, there were no differences in the baseline characteristics of the women between the intervention groups (514 participants allocated to the enhanced and 524 to the standard app group). The dropout rate between early and late pregnancy was 62% (647/1038), which was evenly distributed across the standard and enhanced app groups. In study II, the key differences in background factors between the countries were seen e.g. in the obesity status, smoking habits before pregnancy and educational level (see details in Publication II).

Characteristics of the children and their parents are shown in Table 15. Preschool-aged children from 18 out of 20 hospital districts in the mainland Finland participated in the study III, and 66% of the elementary school-aged children lived in Southwest Finland (Turku area) and 34% in Eastern Finland (Kuopio area, study IV). Of the children, 54% and 48% were girls in the studies III and IV, respectively. In both studies, approximately one fifth of the children had overweight or obesity. Furthermore, less than half of the parents of preschool-aged children had a college or university degree (study III), whereas the proportion was higher in those of the elementary school-aged children (study IV).

Table 14. Characteristics of the pregnant women in the studies I and II.

CHARACTERISTICS	STUDY I (n=1038)		STUDY II (n=1804)							
Country	Finland		Finland (n=536)		Italy (n=556)		Poland (n=591)		The UK (n=121)	
Age (years)	n=1033	29.4 ± 4.0	n=535	30.0 (27.0–33.0)	n=551	32.0 (29.0–35.0)	n=587	28.0 (25.0–31.0)	n=121	32.0 (29.0–35.0)
<25 years		127 (12.3)		45 (8.4)		22 (4.0)		106 (18.1)		16 (13.2)
25–29 years		400 (38.7)		217 (40.6)		142 (25.8)		283 (48.2)		20 (16.5)
30–34 years		408 (39.5)		201 (37.6)		222 (40.3)		162 (27.6)		48 (39.7)
≥35 years		98 (9.4)		72 (13.5)		165 (30.0)		36 (6.1)		37 (30.6)
Pre-pregnancy BMI (kg/m^2)	n=1035	24.8 ± 4.9	n=534	24.1 (21.5–27.6)	n=547	22.6 (20.4–25.5)	n=586	22.7 (20.5–25.5)	n=107	23.4 (21.5–27.1)
Underweight		22 (2.1)		11 (2.1)		40 (7.3)		48 (8.2)		3 (2.8)
Normal weight		634 (61.3)		313 (58.6)		365 (66.7)		369 (63.0)		64 (59.8)
Overweight		237 (22.9)		112 (21.0)		93 (17.0)		133 (22.7)		24 (22.4)
Obesity		142 (13.7)		98 (18.4)		49 (9.0)		36 (6.1)		16 (15.0)
Primiparous	n=1033	561 (54.3)	n=535	336 (62.8)	n=551	359 (65.2)	n=588	430 (73.1)	n=121	80 (66.1)
College or university degree	n=1038	692 (66.7)	n=536	379 (70.7)	n=551	316 (57.4)	n=588	457 (77.7)	n=121	94 (77.7)
Working in the health sector	-	-	n=502	229 (45.6)	n=515	119 (23.1)	n=576	88 (15.3)	n=119	40 (33.6)
Marital status	n=1037		n=534		n=551		n=588		n=120	
Married		520 (50.1)		286 (53.6)		320 (58.1)		442 (75.2)		83 (69.2)
Living with a partner		476 (45.9)		227 (42.5)		225 (40.8)		132 (22.4)		30 (25.0)
Other		41 (4.0)		21 (3.9)		6 (1.1)		14 (2.4)		7 (5.8)
Smoking										
Before pregnancy	n=1038	170 (16.4)	n=534	108 (20.2)	n=551	248 (45.0)	n=585	183 (31.2)	n=121	20 (16.5)
During pregnancy	n=1029	23 (2.2)	n=534	14 (2.6)	n=556	49 (8.9)	n=585	32 (5.5)	n=121	2 (1.7)
Alcohol consumption										
Before pregnancy	-	-	n=535	448 (83.7)	n=549	393 (71.6)	n=587	482 (82.1)	n=121	108 (89.3)
During pregnancy	-	-	n=535	8 (1.5)	n=549	71 (13.0)	n=587	5 (0.9)	n=120	15 (12.5)

Data presented as n (%), mean ± standard deviation or median (lower–upper quartile).

Table 15. Characteristics of the preschool-aged (study III) and elementary school-aged children (study IV).

CHARACTERISTICS	PRESCHOOL-AGED CHILDREN (n=766)		ELEMENTARY SCHOOL-AGED CHILDREN (n=266)	
CHILDREN				
Age (years)	n=766	4.0 (3.0–5.0)	n=266	9.7 ± 1.7
BMI SDS	n=713		n=266	
Underweight		31 (4.3)		13 (4.9)
Normal weight		542 (76.0)		197 (74.1)
Overweight		110 (15.4)		43 (16.2)
Obesity		30 (4.2)		13 (4.9)
PARENTS				
Age (years)				
Mother	n=673	34.0 (31.0–38.0)	n=259	40.8 ± 5.3
Father	n=62	35.5 (32.8–39.0)	n=251	43.2 ± 6.1
BMI (kg/m^2)				
Mother	n=654	24.2 (21.5–27.3)	n=253	23.6 (21.9–27.2)
Father	n=61	25.2 (23.5–27.3)	n=232	25.4 (23.8–28.1)
Smoking				
Mother	n=673	89 (13.2)	n=258	14 (5.4)
Father	n=60	15 (25.0)	n=251	36 (14.3)
College or university degree				
Mother	n=670	331 (49.4)	n=259	202 (78.0)
Father	n=62	26 (41.9)	n=246	148 (60.2)
Annual household income (€)	n=713		n=249	
<20,000		58 (8.1)		6 (2.4)
20,000–40,000		183 (25.7)		33 (13.2)
40,001–60,000		223 (31.3)		46 (18.5)
60,001–80,000		159 (22.3)		62 (24.9)
>80,000		90 (12.6)		102 (41.0)
Self-perceived physical activity level	n=737		-	
Not at all/very little		84 (11.4)		-
Moderate		417 (56.6)		-
Very much		203 (27.5)		-
Extremely much		33 (4.5)		-
Following a self-perceived healthy diet	n=738		-	
Not at all/very little		13 (1.8)		-
Moderately		329 (44.6)		-
A lot		348 (47.2)		-
Extremely much		48 (6.5)		-

Data are presented as mean ± standard deviation, median (lower─upper quartile) or n (%).

5.2 Lifestyle habits of pregnant women (studies I & II)

5.2.1 Diet, physical activity and gestational weight gain during pregnancy (studies I & II)

The lifestyle habits of pregnant women in early and late pregnancy are presented in Table 16 (study I). In early pregnancy, the median IDQ score was 9.0 out of the maximum points of 15. Less than half of the women had a good quality diet. Two out of three women consumed vegetables daily and less than half consumed vegetables, fruits and/or berries at least five portions a day as recommended. Around one third of the women ate fish at least two times a week and usually chose the recommended options of milk or sour milk with max 1% of fat (instead of high fat milk or sour milk) and vegetable oil-based spread on bread (instead of butter or butter-vegetable oil mix) for consumption. Majority of the women had a regular meal pattern (i.e. skipped two or less lunches or dinners per week). Some of the dietary habits were improved as the pregnancy proceeded, namely higher proportion of women consumed whole grains, fruits and berries daily, adhered to the recommended daily portions of vegetables, fruits and berries as well as chose vegetable oil-based spread on bread in late pregnancy. The consumption of selected foods in Finnish pregnant women in the study II are comparable to those in the study I (Table 17). The proportions of women eating vegetables at least twice per day as well as fruits and/or berries and whole grain products daily were highest in Finland when compared to the other countries.

In the study I, the median MET score in early pregnancy was 7.5 MET h/week with almost half of the women having low physical activity level and only 11% reaching the vigorous physical activity level (Table 16). Physical activity further decreased towards the late pregnancy. In the study II, low physical activity levels were common in all countries, with Finnish women being the most likely and Italian and Polish women the least likely to have a vigorous activity level (Table 17).

In the study I, the mean ± SD total gestational weight gain between pre-pregnancy and late pregnancy was 12.1 ± 4.6 kg with 36% (138/383) having ideal weight gain and 32% (124/383) of the women gaining weight in excess according to the IOM recommendation. Of women with overweight or obesity, up to 49% (56/115) had higher that recommended weight gain, whereas the corresponding proportion for women with underweight or normal weight was 25% (100/268).

Table 16. Diet quality and physical activity in early and late pregnancy (study I).

	N EARLY/LATE PREGNANCY	EARLY PREGNANCY (n=1038)[a]	LATE PREGNANCY (n=384)[a]	P-VALUE
DIET QUALITY				
IDQ score	1029/384	9.0 (8.0−11.0)	10.0 (9.0−11.0)	0.36[b]
Good diet quality	1029/384	482 (46.8)	219 (57.0)	0.20[c]
DIET QUALITY COMPONENTS				
Vegetables daily	1029/384	712 (69.2)	279 (72.7)	0.54[c]
Fruits and/or berries daily	1029/384	556 (54.0)	261 (68.0)	<0.001[c]
Vegetables, fruits and/or berries ≥5 portions a day	1029/384	437 (42.5)	211 (54.9)	<0.001[c]
Whole-grain products daily	1023/383	613 (59.9)	286 (74.7)	<0.001[c]
Fish ≥2 times a week	1027/383	292 (28.4)	126 (32.9)	0.065[c]
Milk/sour milk with ≤1% of fat	1028/384	298 (29.0)	108 (28.1)	0.53[c]
Vegetable oil-based spread (with 60–80% of fat) on bread	1025/383	214 (20.9)	112 (29.2)	<0.001[c]
Regular meal pattern[d]	1029/383	921 (89.5)	349 (90.9)	0.23[c]
PHYSICAL ACTIVITY				
MET score	1031/376	7.5 (3.0−15.0)	3.0 (0.5−12.0)	<0.001[b]
Physical activity level	1031/376			<0.001[e]
Low		462 (44.8)	219 (58.2)	
Moderate		452 (43.8)	140 (37.2)	
Vigorous		117 (11.4)	17 (4.5)	

Data are presented as n (%) or median (lower—upper quartile). [a] Total number of participants. [b] Wilcoxon signed rank test. [c] McNemar test. [d] ≤2 lunches or dinners skipped per week. [e] Stuart-Maxwell test.

Table 17. Consumption of selected diet quality components and physical activity levels during pregnancy in four countries (study II).

LIFESTYLE HABITS	FINLAND (n=536)	ITALY (n=556)	POLAND (n=591)	THE UK (n=121)	P-VALUE
DIET QUALITY COMPONENTS					
Vegetables ≥2 times/day	315 (58.8)	113 (20.5)	281 (47.8)	68 (56.2)	<0.001
Fruits and/or berries daily	399 (74.7)	334 (60.7)	430 (73.3)	89 (74.2)	<0.001
Whole grain products daily	420 (78.5)	183 (33.2)	299 (50.9)	77 (64.2)	<0.001
Fish weekly	276 (51.6)	372 (67.6)	242 (41.2)	64 (53.3)	<0.001
PHYSICAL ACTIVITY LEVEL					<0.001
Low	268 (50.5)	448 (82.8)	480 (82.6)	63 (52.1)	
Moderate	224 (42.2)	89 (16.5)	98 (16.9)	56 (46.3)	
Vigorous	39 (7.3)	4 (0.7)	3 (0.5)	1 (1.7)	

Data are presented as n (%). P-values represent comparisons between the countries (Chi-square test with Bonferroni correction). Missing data: Finland n=0−2, Italy n=5−6, Poland n=3−5 and the UK n=0−1 depending on the question.

5.2.2 Food supplement consumption during pregnancy (study II)

Food supplement consumption

As shown in the study II, most participants (98%, 526/536) in Finland reported using at least one supplement product during pregnancy, whereas the proportion of supplement users in the other countries were slightly lower: 83% (462/556) in Italy, 93% (549/591) in Poland and 90% (109/121) in the UK. Supplement users were more likely primiparous (the result corrected from Publication II) and non-smokers prior to pregnancy than women not using supplements (Table 18). Among the food supplement users, the most commonly used food supplement types among Finnish women were prenatal multivitamin products (82%, see details in Publication II). Similar findings were reported in the other countries with 76% of the participants consuming prenatal multivitamins in Italy, 91% in Poland and 87% in the UK. Iron was the second most commonly used supplement in Finland (40%), folic acid in Italy (50%), magnesium in Poland (49%) and general multivitamin products in the UK (25%).

The number of supplement products consumed by the Finnish women was 1−9 per person, whereas in the other countries the maximum number of supplement products consumed was 5−7. It was most common to consume only one supplement product at a time in Finland (29%) and in the other countries with the proportions ranging from 41% of participants in Poland to 54% in Italy (Figure 4). Up to one-fifth of the Finnish women used at least four food supplement products simultaneously, whereas the corresponding proportion was 5–10% in the other countries.

Table 18. Likelihood of any food supplement use according to selected demographic and behavioural factors characterising pregnant women in four European countries. Modified from Publication II.

	N	ADJUSTED OR[a]	95% CONFIDENCE INTERVAL	P-VALUE[b]
DEMOGRAPHIC FACTORS				
Age, years	1794			0.48
<25 years		1		
25–29 years		1.51	0.83–2.77	
30–34 years		1.26	0.69–2.28	
≥35 years		1.13	0.59–2.16	
Pre-pregnancy BMI (kg/m^2)	1774			0.50
Underweight		1		
Normal weight		1.48	0.80–2.74	
Overweight		1.23	0.62–2.43	
Obesity		1.69	0.73–3.91	
Marital status	1793			0.063
Living with a partner		1		
Married		1.34	0.94–1.91	
Other		0.55	0.21–1.40	
Primiparous	1795			<0.001
No		1		
Yes		1.85	1.32–2.61	
Education	1796			0.47
Secondary education or lower		1		
College or university degree		1.14	0.80–1.63	
Working in the health sector	1712			0.52
No		1		
Yes		1.15	0.75–1.77	
BEHAVIOURAL FACTORS				
Regular smoking before pregnancy	1794			0.047
No		1		
Yes		0.68	0.46–0.99	
Alcohol consumption before pregnancy	1792			0.45
Not at all		1		
<1 drink per week		1.40	0.91–2.14	
1–2 drinks per week		1.16	0.73–1.84	
3–7 drinks per week		1.74	0.84–3.62	
>7 drinks per week		0.94	0.26–3.41	
Physical activity level during pregnancy	1774			0.73
Low		1		
Moderate		0.89	0.59–1.36	
High		1.80	0.23–13.81	
Consuming vegetables ≥2 times/day	1795			0.47
No		1		
Yes		1.15	0.79–1.68	
Consuming fruits and/or berries daily	1791			0.75
No		1		
Yes		0.94	0.66–1.35	
Consuming whole grain products daily	1635			0.83
No		1		
Yes		1.04	0.73–1.48	
Consuming fish weekly	1792			0.91
No		1		
Yes		0.98	0.69–1.39	

[a] Adjusted by country. [b] Logistic regression analysis with a univariate approach.

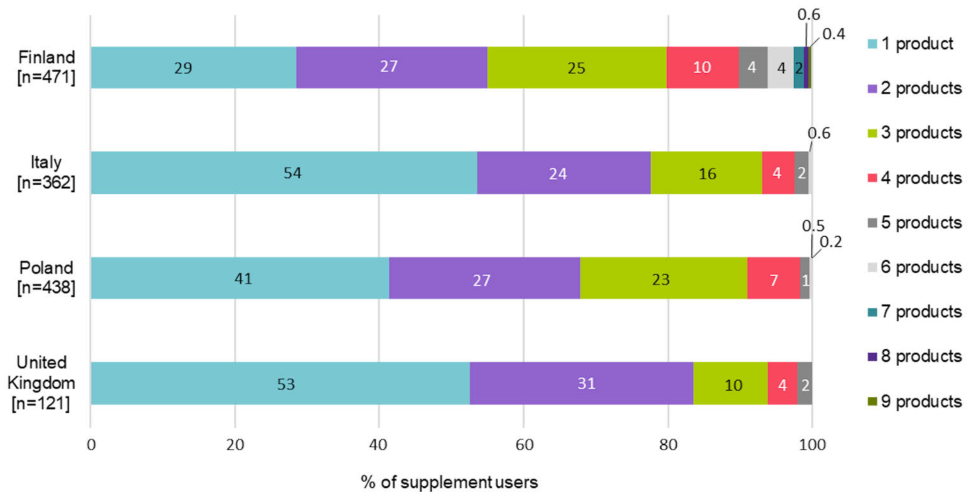

Figure 4. Proportion of supplement users using one or more food supplement products. Modified from Publication II.

Adherence to food supplement recommendations

The daily intakes of nutrients from the food supplements and adherence to food supplement recommendations in each country are reported in Table 19. Most participants in Finland (93%) and in the other countries (95−98%) used folic acid supplements, which is recommended in all four countries. Half of the folic acid supplement users in Finland used the recommended dose; in the other countries the proportion adhering to the recommendation varied between 26% (Poland) and 90% (the UK). Further, 11% (46/437) of folic acid supplement users in Finland used less than the recommended dose, while the respective proportions in the other countries were 3% (10/342) in Italy, 4% (17/432) in Poland and 2% (2/92) in the UK.

In Finland, 97% of the participants used vitamin D supplements, whereas in Poland and the UK the respective proportions were 91%, and 95%. In Italy, 77% of the participants used vitamin D as a supplement although the country has not issued a recommendation for the use of vitamin D supplements during pregnancy. In Finland, less than 60% of the women used the recommended dose of vitamin D supplement. The proportion adhering to the vitamin D recommendation was similar in Poland (56%), but higher in the UK (84%). The proportion of women using less than the recommended dose of vitamin D supplement was 9% (39/456) in Finland, whereas the respective proportion was 2% (2/92) in the UK and 36% (144/399) in Poland.

It is of note that in Poland, also iodine is recommended to be used as a supplement during pregnancy. Majority of the Polish women (86%) used iodine supplements and most of them (64%) adhered to the recommended intake, whereas 33% (123/378) used a lower dose than recommended.

In Finland, the recommended doses for folic acid and vitamin D supplements were exceeded by around third of the participants, of which 2% also exceeded the safe upper intake limits of the supplements. In Poland, 70% of folic acid supplement users exceeded the recommended dose and 10% of them also exceeded the safe upper intake limit, but only 8% and 2% did so, respectively, in the UK. Regarding vitamin D supplements, 14% in the UK and 8% in Poland exceeded the recommended dose and of them, 2% exceeded the safe upper intake limits in both countries. Of the supplement users in Finland, 20% (92/470) exceeded the daily safe upper intake limit of at least one nutrient with the respective proportions in the other countries being 25% (91/360) in Italy, 17% (76/437) in Poland, and 6% (6/97) in the UK. The proportions of participants exceeding the daily safe upper intake limits were the highest with magnesium supplements; 20% of magnesium supplement users in Finland exceeded the limit, whereas in the other countries the proportion ranged from 4% (the UK) to 29% (Italy).

Table 19. Daily intakes of nutrients from food supplements and adherence to food supplement recommendations in pregnant women who reported their supplement use with pictures and/or detailed written information. Modified from Publication II.

NUTRIENT	FINLAND (n=470)	ITALY (n=360)	POLAND (n=439)	THE UK (n=97)	P-VALUE
Vitamin A, μg/d					
User, n (%)	4 (0.9)	31 (8.6)	7 (1.6)	1 (1.0)	<0.001[a]
Dose, median (Q1−Q3)	400.0 (325.0–700.0)	300.0 (300.0–300.0)	800.0 (640.0–800.0)	800.0	0.036[b]
Dose, range	300.0–800.0	300.0–1080.0	400.0–1080.0	-	
Exceeding the daily safe upper intake limit of 3000 μg/d [c], n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Vitamin B6 (pyridoxine), mg/d					
User, n (%)	404 (86.0)	284 (78.9)	310 (70.6)	79 (81.4)	<0.001[a]
Dose, median (Q1−Q3)	5.0 (2.8–5.0)	1.9 (1.4–1.9)	2.6 (2.2–5.0)	10.0 (1.9–10.0)	<0.001[b]
Dose, range	0.5–51.2	0.6–20.9	0.6–100.0	1.4–30.0	
Exceeding the daily safe upper intake limit of 25 mg/d [c], n (%)	6 (1.5)	0 (0.0)	16 (5.2)	1 (1.3)	
Vitamin B9 (folic acid), μg/d [d]					
User, n (%)	437 (93.0)	342 (95.0)	432 (98.4)	92 (94.8)	0.006[a]
Dose, median (Q1−Q3)	400.0 (400.0–500.0)	400.0 (400.0–400.0)	800.0 (400.0–800.0)	400.0 (400.0–400.0)	<0.001[b]
Dose, range	100.0–1500.0	142.9–16200.0	114.3–6600.0	171.4–5400.0	
Meeting the recommended dose, n (%)	240 (54.9)	258 (75.4)	112 (26.0)	83 (90.2)	
Exceeding the recommended dose, n (%)	151 (34.6)	74 (21.6)	303 (70.1)	7 (7.6)	
Exceeding the daily safe upper intake limit of 1000 μg/d [c], n (%)	7 (1.6)	43 (12.6)	43 (10.0)	2 (2.2)	
Vitamin D, μg/d [e]					
User, n (%)	456 (97.0)	277 (76.9)	399 (90.9)	92 (94.8)	<0.001[a]
Dose, median (Q1−Q3)	10.0 (10.0–20.0)	12.5 (10.0–15.0)	50.0 (20.0–50.0)	10.0 (10.0–10.0)	<0.001[b]
Dose, range	0.9–253.3	3.6–250.0	2.5–332.5	4.3–85.0	
Meeting the recommended dose, n (%)	266 (58.3)	-	224 (56.1)	77 (83.7)	
Exceeding the recommended dose, n (%)	151 (33.1)	-	31 (7.8)	13 (14.1)	

NUTRIENT	FINLAND (n=470)	ITALY (n=360)	POLAND (n=439)	THE UK (n=97)	P-VALUE
Exceeding the daily safe upper intake limit of 100 µg/d [c], n (%)	9 (2.0)	5 (1.8)	7 (1.8)	0 (0.0)	
Vitamin E, mg/d					
User, n (%)	385 (81.9)	166 (46.1)	215 (49.0)	71 (73.2)	<0.001 [a]
Dose, median (Q1−Q3)	15.0 (12.0–15.0)	12.0 (8.0–12.0)	11.7 (11.7–23.4)	4.0 (4.0–12.0)	<0.001 [b]
Dose, range	2.3–30.0	3.0–280.0	1.0–130.0	1.7–200.0	
Exceeding the daily safe upper intake limit of 300 mg/d [c], n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Calcium, mg/d					
User, n (%)	113 (24.0)	114 (31.7)	40 (9.1)	36 (37.1)	<0.001 [a]
Dose, median (Q1−Q3)	500.0 (400.0–750.0)	140.0 (140.0–242.5)	200.0 (200.0–240.0)	200.0 (120.0–500.0)	<0.001 [b]
Dose, range	42.9–1100.0	36.9–731.0	70.0–1000.0	120.0–1120.0	
Exceeding the daily safe upper intake limit of 2500 mg/d [c], n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Magnesium, mg/d					
User, n (%)	390 (83.0)	181 (50.3)	241 (54.9)	77 (79.4)	<0.001 [a]
Dose, median (Q1−Q3)	180.0 (180.0–180.0)	110.0 (60.0–110.0)	90.0 (50.0–193.0)	150.0 (150.0–150.0)	<0.001 [b]
Dose, range	37.5–930.0	9.0–1140.0	2.4–600.0	60.0–410.0	
Exceeding the daily safe upper intake limit of 250 mg/d [c], n (%)	76 (19.5)	52 (28.7)	28 (11.6)	3 (3.9)	
Zinc, mg/d					
User, n (%)	382 (81.3)	266 (73.9)	99 (22.6)	77 (79.4)	<0.001 [a]
Dose, median (Q1−Q3)	15.0 (10.7–15.0)	10.0 (10.0–11.0)	15.0 (11.0–15.0)	15.0 (15.0–15.0)	<0.001 [b]
Dose, range	2.0–40.0	0.9–22.5	3.8–101.0	6.4–25.0	
Exceeding the daily safe upper intake limit of 25 mg/d [c], n (%)	4 (1.0)	0 (0.0)	2 (2.0)	0 (0.0)	
Selenium, µg/d					
User, n (%)	369 (78.5)	210 (58.3)	138 (31.4)	77 (79.4)	<0.001 [a]
Dose, median (Q1−Q3)	60.0 (55.0–60.0)	55.0 (30.0–55.0)	55.0 (55.0–55.0)	30.0 (30.0–55.0)	<0.001 [b]

NUTRIENT	FINLAND (n=470)	ITALY (n=360)	POLAND (n=439)	THE UK (n=97)	P-VALUE
Dose, range	12.5–88.0	12.5–112.5	16.0–200.0	12.9–150.0	
Exceeding the daily safe upper intake limit of 300 μg/d [c], n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Iodine, μg/d [f]					
User, n (%)	379 (80.6)	266 (3.9)	378 (86.1)	76 (78.4)	<0.001 [a]
Dose, median (Q1−Q3)	175.0 (175.0–200.0)	200.0 (175.0–220.0)	200.0 (150.0–200.0)	150.0 (150.0–150.0)	<0.001 [b]
Dose, range	37.5–220.0	64.3–440.0	50.0–400.0	50.0–290.0	
Meeting the recommended dose, n (%)	-	-	241 (63.8)	-	
Exceeding the recommended dose, n (%)	-	-	14 (3.7)	-	
Exceeding the daily safe upper intake limit of 600 μg/d [c], n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

[a] Comparison between the countries, Chi-square test with Bonferroni correction. [b] Comparison between the countries, Kruskal–Wallis test with Bonferroni correction. [c] Safe upper intake limit reported as set by the European Food Safety Authority [289]. [d] Recommended intake of folic acid from supplements during pregnancy: 400 μg/d in the low-risk group until the 12th pregnancy week in Finland, Italy and the UK and for the whole pregnancy time in Poland. [e] Recommended intake of vitamin D from supplements during pregnancy: 10 μg/d in Finland and the UK, 50 μg/d in Poland, no recommendation in Italy. [f] Recommended intake of iodine from supplements during pregnancy: 200 μg/d in Poland, no recommendation in the other countries.

5.3 Effects of health app use and additional health information provided by the app on lifestyle habits during pregnancy (study I)

5.3.1 Characterisation of app use

Of the participants in the study I, 76% signed up for the app, and 37% of them made at least one recording (app users), while the remaining 63% did not use the app (app non-users). App users made a median (Q1–Q3) of 59 (19–294) recordings across the study period with a total range of 2−4651 recordings. The median (Q1–Q3) duration of app use was 4.7 weeks (1.1–15.6) with a total range of 0.1–35.1 weeks (Figure 5). The most commonly used recording type was the number of meals consumed daily, representing 23% of all recordings followed by the consumption of water (16%), fruits (10%) and vegetables (10%). For further analyses, the app users were categorised based on the duration of app use; 'frequent app users' used the app for at least 4.7 weeks and 'occasional app users' used the app at least once, but for less than 4.7 weeks.

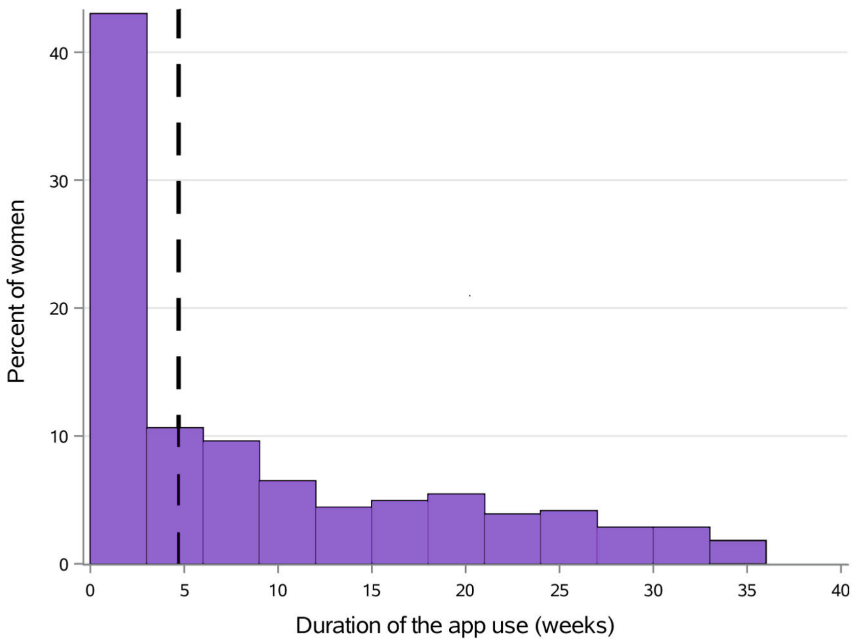

Figure 5. Duration of the app use among the participants. Dashed line denotes the median duration of the app use. Modified from Publication I.

5.3.2 Characterisation of app users

Several demographic and behavioural factors were found to associate with the frequency of app use (Table 20). The between-group comparisons showed that having underweight or normal weight (p=0.017) and being a non-smoker (p=0.015) prior to pregnancy were more likely in frequent app users than in app non-users. Frequent app users were also more likely to be primiparous (p=0.001), married (p=0.002) and to have a university education (p=0.005) compared to app non-users. Having a university education was also more likely in occasional app users than in non-users (p=0.001). Regarding the lifestyle factors, the IDQ scores were higher in frequent app users than in app non-users in early pregnancy (p=0.002, Table 21). It was also more common for frequent app users to eat fruits and/or berries daily compared with app non-users in early pregnancy (p=0.006) and with occasional app users in late pregnancy (p=0.004, Table 21).

5.3.3 Effects of the app use frequency on the lifestyle habits

When assessing the effects of the app use frequency on the changes in gestational weight, IDQ scores and diet quality components as well as MET scores between early and late pregnancy, no differences were found between frequent app users, occasional app users and app non-users (Table 21). Mixed effects logistic regression model indicated that the proportion of women with moderate or vigorous activity level decreased between early and late pregnancy (OR 0.54, 95% CI 0.43, 0.67, p<0.001), but less in frequent (OR 0.61, 95% CI 0.40–0.94, p=0.025) and occasional app users (OR 0.55, 95% CI 0.32–0.97, p=0.04) compared to non-users (time×group interaction, p=0.036).

Table 20. Factors characterising the frequency of using the health app. Modified from Publication I.

DEMOGRAPHIC FACTORS	N NON-USER/ OCCASIONAL USER/ FREQUENT USER	NON-USER (n=652)[a]	OCCASIONAL USER (n=193)[a]	FREQUENT USER (n=193)[a]	P-VALUE
Age (years)	651/190/192	29.2 ± 4.2	29.7 ± 3.5	29.4 ± 3.9	0.41[b]
Pre-pregnancy weight status	650/192/193				0.030[c]
Underweight/normal weight		403 (62.0)	115 (59.9)	138 (71.5)	
Overweight/obesity		247 (38.0)	77 (40.1)	55 (28.5)	
Primiparous	648/192/193	331 (51.1)	106 (55.2)	124 (64.2)	0.005[c]
Married	652/192/193	304 (46.6)	102 (53.1)	114 (59.1)	0.007[c]
Place of residence	651/193/193				0.80[c]
Southern Finland		281 (43.2)	83 (43.0)	88 (45.6)	
Western Finland		256 (39.3)	70 (36.3)	76 (39.4)	
Eastern Finland		48 (7.4)	15 (7.8)	10 (5.2)	
Northern Finland		66 (10.1)	25 (13.0)	19 (9.8)	
Education level	652/193/193				<0.001[c]
Secondary education or lower		246 (37.7)	49 (25.4)	51 (26.4)	
University or college degree		406 (62.3)	144 (74.6)	142 (73.6)	
Yearly income (€)	646/191/193				0.44[c]
<20.000		58 (9.0)	11 (5.8)	13 (6.7)	
20.000–40.000		185 (28.6)	46 (24.1)	49 (25.4)	
40.001–60.000		169 (26.2)	56 (29.3)	51 (26.4)	
>60.000		234 (36.2)	78 (40.8)	80 (41.5)	
Work position	540/168/158				0.32[c]
Worker (manual worker)		307 (56.9)	95 (56.6)	76 (48.1)	
Employee (clerical worker)		107 (19.8)	35 (20.8)	30 (19.0)	
Managerial employee/manager		99 (18.3)	31 (18.5)	41 (26.0)	
Entrepreneur		27 (5.0)	7 (4.2)	11 (7.0)	
Smoking status					
Smoking before pregnancy	652/193/193	119 (18.3)	30 (15.5)	21 (10.9)	0.049[c]
Smoking during pregnancy	650/192/187	13 (2.0)	6 (3.1)	4 (2.1)	0.65[c]

Data presented as mean ± standard deviation or n (%). [a] The full number of participants (in the group). [b] One-way ANOVA. [c] Chi-squared test.

Table 21. Efficacy of the health app use in improving lifestyle habits during pregnancy in app non-users, occasional app users and frequent app users. Modified from Publication I.

LIFESTYLE HABITS	N NON-USER/ OCCASIONAL USER/ FREQUENT USER	NON-USER (n=652)[a]	OCCASIONAL USER (n=193)[a]	FREQUENT USER (n=193)[a]	P-VALUE
DIET QUALITY SCORES					
IDQ scores in early pregnancy	646/192/191	9.0 (8.0–11.0)	9.3 (8.0–11.0)	10.0 (8.0–11.0)	0.002[b]
IDQ scores in late pregnancy	171/69/144	10.0 (9.0–11.0)	10.0 (8.1–11.0)	10.0 (9.0–11.0)	0.41[b]
Change in IDQ scores between early and late pregnancy	171/68/143	0.0 (-1.0–1.0)	0.0 (-1.0–1.0)	0.0 (-1.0–1.0)	0.88[b]
DIET QUALITY COMPONENTS					
Regular eating frequency[c] in early pregnancy	646/192/191	568 (87.9)	176 (91.7)	177 (92.7)	0.10[d]
Regular eating frequency[c] in late pregnancy	171/69/144	154 (90.1)	65 (94.2)	130 (90.3)	0.57[d]
Eating vegetables daily in early pregnancy	646/192/191	434 (67.2)	136 (70.8)	142 (74.4)	0.15[d]
Eating vegetables daily in late pregnancy	171/69/144	122 (71.4)	49 (71.0)	108 (75.0)	0.73[d]
Eating fruits and/or berries daily in early pregnancy	646/192/191	329 (50.9)	108 (56.3)	119 (62.3)	0.017[d]
Eating fruits and/or berries daily in late pregnancy	171/69/144	114 (66.7)	38 (55.1)	109 (75.7)	0.009[d]
Eating vegetables, fruits and/or berries ≥5 portions/day in early pregnancy	646/192/191	265 (41.0)	83 (43.2)	89 (46.6)	0.38[d]
Eating vegetables, fruits and/or berries ≥5 portions/day in late pregnancy	171/69/144	95 (55.6)	33 (47.8)	83 (57.6)	0.39[d]
WEIGHT					
Change in weight between early and late pregnancy, kg	168/73/142	8.0 (5.0–11.0)	9.0 (5.0–11.0)	9.0 (6.0–12.0)	0.083[b]
Weekly weight gain rate, kg	167/73/141	0.4 (0.3–0.6)	0.5 (0.3–0.6)	0.4 (0.3–0.6)	0.73[b]
PHYSICAL ACTIVITY					
MET scores in early pregnancy	649/191/191	7.5 (3.0–15.0)	7.5 (2.0–12.0)	7.5 (3.0–18.8)	0.056[b]
MET scores in late pregnancy	167/67/142	3.0 (0.8–7.5)	4.8 (0.8–12.0)	3.0 (0.5–12.0)	0.80[b]
Change in MET scores between early and late pregnancy	165/67/140	-2.5 (-7.5–0.0)	0.0 (-4.8–1.5)	-2.4 (-9.3–0.0)	0.082[b]

Data presented as median (lower−upper quartile) or n (%). [a] The full number of participants in the group. [b] Kruskal-Wallis test. [c] ≤2 lunches or dinners skipped per week. [d]Chi-squared test.

5.3.4 Intervention effects on the lifestyle habits

The provision of evidence-based health information via the app had no effects on the gestational weight gain and in the changes in IDQ or MET scores (Table 22). In early pregnancy, the women in the enhanced app group had higher IDQ scores than those in the standard app group (p=0.02), but the difference was no longer evident in late pregnancy. The results considering IDQ scores in early pregnancy (adjusted p=0.023), late pregnancy (adjusted p=0.50) and the change between the time points (adjusted p=0.25) did not change after adjustments (mother's age, parity, marital status, educational level and pre-pregnancy BMI). Moreover, there were no differences in the diet quality components in early and late pregnancy between the intervention groups (Table 22). Mixed effects logistic regression model for regular eating frequency showed significant time×group interaction (p=0.041): the proportion of women with regular eating frequency was lower in late than in early pregnancy in the enhanced app group (OR 0.47, 95% CI (0.22, 0.98), p=0.045), but no difference was detected in the standard app group (OR 1.44, 95% CI (0.69, 3.01), p=0.33). No other differences were found with regard to the changes in diet quality components between the time points (data not shown). Further, there were no differences between the intervention groups in body weight and MET scores in early or late pregnancy.

The intervention effect was also studied exclusively within frequent app users. In these analyses, no differences were shown in gestational weight gain, changes in IDQ or MET scores, or in diet quality components between the intervention groups (see details in Publication I). However, frequent use of the enhanced app was associated with higher MET scores in late pregnancy compared with frequent use of the standard app (4.8 (1.2–12.0) vs. 2.0 (0.0–7.5) respectively, p=0.015). Frequent use of the enhanced app was also associated with higher IDQ scores in early pregnancy compared with frequent use of the standard app (10.1±2.0 vs. 9.5±2.1 respectively, p=0.04), but this difference levelled off by the late pregnancy. The IDQ scores did no longer differ between the groups after adjustments (mother's age, parity, marital status, educational level and pre-pregnancy BMI; adjusted p=0.086); other IDQ results remained essentially the same.

Table 22. Efficacy of additional evidence-based health information delivered via the health app in improving lifestyle during pregnancy between the standard app and enhanced app groups in all app users. Modified from Publication I.

	TOTAL N	ALL (n=386)[a]	STANDARD APP GROUP (n=206)[a]	ENHANCED APP GROUP (n=180)[a]	P-VALUE
DIET QUALITY SCORES					
IDQ scores in early pregnancy	383/205/178	9.6 ± 2.0	9.4 ± 2.1	9.9 ± 1.9	0.019[b]
IDQ scores in late pregnancy	214/115/99	9.8 ± 2.0	9.8 ± 1.9	9.9 ± 2.2	0.59[b]
Change in IDQ scores between early and late pregnancy	212/114/98	0.05 ± 1.7	0.2 ± 1.5	-0.08 ± 1.8	0.31[b]
DIET QUALITY COMPONENTS					
Regular eating frequency[c] in early pregnancy	383/205/178	353 (92.2)	185 (90.2)	168 (94.4)	0.18[d]
Regular eating frequency[c] in late pregnancy	213/114/99	195 (91.5)	107 (93.9)	88 (88.9)	0.22[d]
Eating vegetables daily in early pregnancy	383/205/178	278 (72.6)	145 (70.7)	133 (74.7)	0.42[d]
Eating vegetables daily in late pregnancy	213/114/99	157 (73.7)	78 (68.4)	79 (79.8)	0.063[d]
Eating fruits and/or berries daily in early pregnancy	383/205/178	227 (59.3)	115 (56.1)	112 (62.9)	0.21[d]
Eating fruits and/or berries daily in late pregnancy	213/114/99	147 (69.0)	78 (68.4)	69 (69.7)	0.88[d]
Eating vegetables, fruits and/or berries ≥5 portions/day in early pregnancy	383/205/178	172 (44.9)	85 (41.5)	87 (48.9)	0.15[d]
Eating vegetables, fruits and/or berries ≥5 portions/day in late pregnancy	213/114/99	116 (54.5)	58 (50.9)	58 (58.6)	0.27[d]
WEIGHT					
Change in weight between early and late pregnancy, kg	215/112/103	9.3 ± 4.7	9.5 ± 5.0	9.2 ± 4.3	0.56[b]
Weekly weight gain rate, kg	215/112/103	0.5 ± 0.2	0.5 ± 0.2	0.4 ± 0.2	0.22[b]
PHYSICAL ACTIVITY					
MET scores in early pregnancy	382/204/178	7.5 (3.0–12.0)	7.5 (3.0–15.0)	7.5 (3.0–12.0)	0.56[e]
MET scores in late pregnancy	210/113/97	3.0 (0.5–12.0)	3.0 (0.3–8.4)	4.8 (1.2–12.0)	0.074[e]
Change in MET scores between early and late pregnancy	208/112/96	-1.0 (-9.0–0.0)	-1.8 (-10.4–0.0)	-0.38 (-8.2–0.0)	0.38[e]

IDQ, Index of Diet Quality; MET, metabolic equivalent. Data are presented as mean ± standard deviation, median (lower – upper quartile) or n (%). [a] The full number of participants (in the group) among app users. [b] Independent samples T-test. [c] ≤2 lunches or dinners skipped per week. [d] Fisher's Exact test. [e] Mann-Whitney U test.

5.4 Diet of children and association with child weight and background factors (studies III & IV)

5.4.1 Diet in preschool-aged children (study III)

In the study III, the mean ± SD diet quality score in preschool-aged children was 11.1 ± 2.9 out of the maximum score of 18 as assessed with the CIDQ. Good diet quality was found in 14% (101/738), moderate in 55% (409/738) and poor diet quality in 31% (228/738) of the children. Forty-five percent (330/738) of the children consumed vegetables and 37% (276/738) consumed fruits on a daily basis. Further, 5% (36/738) consumed berries daily. However, only 1% (7/726) of the children consumed at least five portions of vegetables, fruits and/or berries per day as recommended. Of the children, 41% (305/739) usually chose fat-free milk (instead of milk containing fat) and 38% (282/738) chose vegetable oil-based spread on bread (instead of butter or butter-vegetable oil mix) for consumption as recommended.

5.4.1.1 Diet quality in relation to preschool-aged child's overweight/obesity status

There was no significant difference in the CIDQ scores between the combined underweight/normal weight group and the combined overweight/obesity group of children (11.1 ± 2.6 and 10.8 ± 2.6 respectively, p=0.35). No differences were found in the categorised diet quality between the groups either (p=0.28, Figure 6).

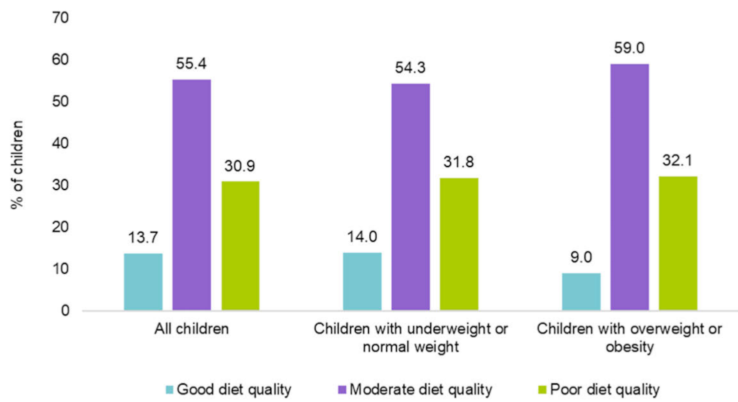

Figure 6. Diet quality categories in all children (n=685), children with underweight or normal weight (n=551) and children with overweight or obesity (n=134). There was no difference in the diet quality categories between the children with underweight/normal weight and their counterparts with overweight/obesity (Chi-squared test). Modified from Publication III.

5.4.1.2 Preschool-aged child's and parental demographic factors associated with child diet quality

From several preschool-aged child and parental demographic factors, child's age, parent's education and parent's self-perceived healthiness of diet were associated with child's CIDQ score in a linear mixed model analysis (Table 23). The CIDQ scores were higher in 2-year-old children than in their 4-year-old and 5-year-old counterparts. Children of parents with a university education had higher CIDQ scores than children whose parents had a college education or secondary or lower education. Furthermore, the CIDQ scores were higher in children of parents with a self-perceived healthier diet than in those with a self-perceived less healthy diet.

Table 23. Linear mixed model analysis for the association of preschool-aged child's and parental demographic factors and CIDQ scores (n=582). Modified from Publication III.

DEMOGRAPHIC FACTORS	CIDQ SCORES	OVERALL P-VALUE	P-VALUE[a]
CHILD	Adjusted mean[b] (SE)		
Age (years)		0.001	
2	11.7 (0.3)		1
3	11.1 (0.3)		0.55
4	10.6 (0.3)		0.006[c]
5	10.5 (0.3)		0.001[c]
6	10.9 (0.3)		0.069
Sex		0.71	
Female	11.0 (0.3)		
Male	10.9 (0.3)		
PARENT			
Mother's age (years)		0.059	
<30.0	11.0 (0.3)		1.00
30.0–34.9	10.6 (0.3)		0.041[c]
35.0–39.9	11.4 (0.3)		1
≥40.0	10.9 (0.3)		0.97
Educational level		0.015	
Secondary education or lower	10.6 (0.2)		0.018[c]
College	10.7 (0.3)		0.026[c]
University	11.6 (0.4)		1
Annual household income (€)		0.24	
<20,000	10.5 (0.4)		1
20,000–40,000	11.0 (0.3)		1.00
40,001–60,000	11.2 (0.3)		0.44
>60,000	11.3 (0.3)		0.39
Self-perceived physical activity level		0.40	
Not at all/very little	10.6 (0.4)		1
Moderate	11.2 (0.2)		0.65
Very much	11.0 (0.3)		1.00
Extremely much	11.1 (0.6)		1.00
Self-perceived healthiness of diet		<0.001	
Not at all/very little/moderately	10.6 (0.3)		
A lot/extremely much	11.4 (0.3)		
Smoking		0.73	
Yes	10.9 (0.4)		
No	11.0 (0.2)		

CIDQ, the Children's Index of Diet Quality. SE, standard error. [a] P-values for pairwise comparisons after Bonferroni correction. [b] Adjusted for all other variables included in the model. Town of living was included as a random effect. [c] Significant difference after Bonferroni correction compared to reference category.

5.4.2 Diet in elementary school-aged children (study IV)

Based on the FFQ data, 51% (133/263) of the elementary school-aged children consumed vegetables, 33% (87/264) consumed fruits and 3% (7/261) consumed berries daily. Only 12% (36/264) of the children consumed at least five portions of vegetables, fruits and/or berries a day as recommended and 35% (92/262) consumed fish at least two portions a week. More than half (56%, 148/263) of the children usually consumed the recommended option of fat-free milk. Furthermore, 38% (100/263) of the children consumed the recommended option of vegetable oil-based spread with at least 60% of fat on bread. Most of the children had a regular eating frequency, i.e. they were eating at intervals of 3–4 h, during the weekdays (85%, 213/251) and weekend days (73%, 191/263). Further details on the food consumption, food intake and the intakes of energy and energy-adjusted nutrients of the children are reported in Supplementary Tables 3 and 4.

Two dietary patterns were identified from the children's food intake: 'Healthier pattern' characterised by higher consumption of e.g. vegetables, fruits and berries, whole grain and fish and 'Unhealthier pattern' with higher consumption of e.g. butter and other fats, meat and high-fat dairy products (Figure 7). These components explained 21% of the total variance in the data. Of the children, 46% (122/266) adhered to the healthier pattern.

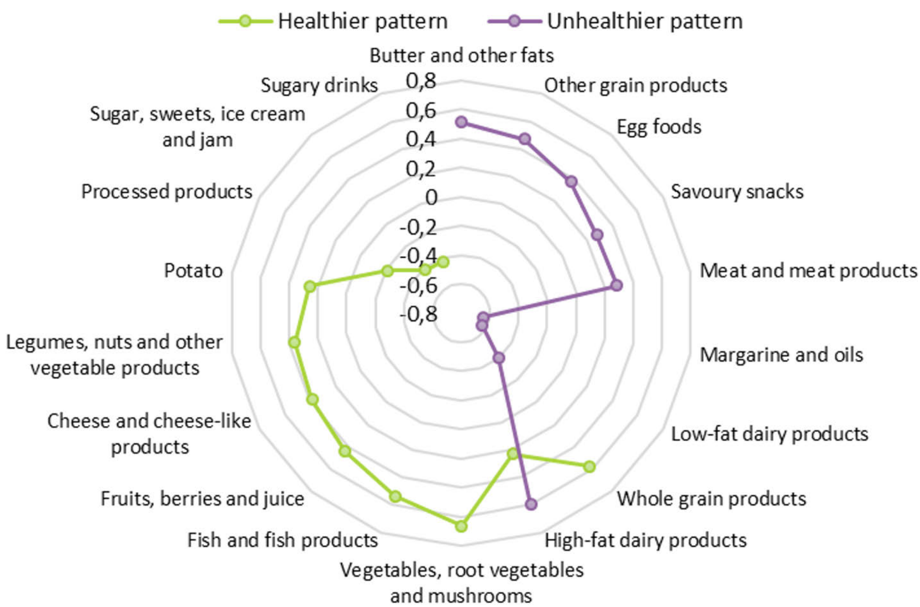

Figure 7. Components and factor loadings (>0.2 and <-0.2) of the child's dietary patterns (a healthier and an unhealthier dietary pattern) identified from children's food intake.

5.4.2.1 Elementary school-aged child's and parental factors associated with dietary patterns

Living in Eastern Finland (Kuopio area) and child's male sex were associated with the adherence to the healthier pattern (Table 24). Furthermore, children with fathers younger than 45 years of age and those whose fathers had university education were more likely to adhere to the healthier pattern (Table 24). Father's smoking habits and mother's age and education were not related to the adherence to the dietary patterns.

Table 24. Child and parental factors associated with child's adherence to a healthy dietary pattern in multivariable logistic regression analyses.

DEMOGRAPHIC FACTORS	MODEL 1 MATERNAL AND CHILD FACTORS		MODEL 2 PATERNAL AND CHILD FACTORS	
	Adjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Child's sex		0.004		0.001
Male	2.2 (1.3–3.7)		2.5 (1.4−4.6)	
Female	1		1	
Area of living		<0.001		<0.001
Eastern Finland (Kuopio area)	2.8 (1.6–4.9)		3.2 (1.7−5.9)	
Southwest Finland (Turku area)	1		1	
Mother's age (years)		0.11		-
<40	1.5 (0.9–2.6)		-	
≥40	1		-	
Father's age (years)		-		<0.001
<45	-		2.8 (1.5–5.2)	
≥45	-		1	
Parent has a university-level degree		0.10		0.047
Yes	1.7 (0.9–3.4)		1.8 (1.0–3.3)	
No	1		1	
Father has a habit of smoking		-		0.082
No	-		2.3 (0.9–5.6)	
Yes	-		1	

CI, confidence interval; OR, odds ratio. OR >1 indicates greater odds for child's adherence to a healthy dietary pattern.

5.5 Diet quality index for elementary school-aged children (study IV)

From the original set of questions from the FFQ, 15 questions were identified as the best ones to describe the elementary school-aged child's adherence to the health-promoting diet criteria. The questions were used to construct the final index, ES-CIDQ, with the total score range of 0−16.5 points (Table 25). A cut-off point of 6 points was identified with ROC curve analysis: children with the index score of <6 points had poor diet quality and those with ≥6 points had good diet quality. With the chosen cut-off point, the sensitivity to identify the children with good diet quality was 0.60 (95% CI 0.53, 0.67) and the specificity was 0.78 (95% CI 0.68, 0.87, Figure 8). Further, the area under the ROC curve for a good diet quality, depicting the accuracy of the index in distinguishing children based on their diet quality scores, was 0.74 (95% CI 0.67, 0.80).

Table 25. Questions chosen for the final diet quality index and scoring of the questions. Modified from Publication IV.

HEALTH-PROMOTING DIET CRITERIA	QUESTIONS IN THE FINAL INDEX	INDEX POINTS
Saturated fatty acids (<10 E%)	Type of milk (fat %)	0–2
	Cheese (fat % & consumption days/week)	0–1
	Type of spread (fat %)	0–1
Sucrose (<10 E%)	Sugary beverages (days/week)	0–2
Dietary fibre (2–3 or ≥3 g/MJ)	Porridge and/or whole grain cereals (days/week)	0–1
Calcium (≥700 or ≥900 mg/d)	Portions of milk (per day)	0–1
	Non-sugary dairy products (days/week)	0–1
Zinc (≥7 or ≥8/11 mg/d)	Fish (days/week)	0–0.5
	Nuts (days/week)	0–1
Vitamin C (≥40 or ≥50 mg/d)	Vegetables (days/week)	0–1
	Fruits (days/week)	0–1
	Berries (days/week)	0–1
Vegetables, fruits and berries (≥250 g/d)	Vegetables, fruits and/or berries (per day)	0–1
	Eating snacks between meals (days/week)	0–1
	Eating habits differ between weekdays and weekend days	0–1
TOTAL SCORE		**0–16.5**

E%, percent of energy intake; MJ, megajoule.

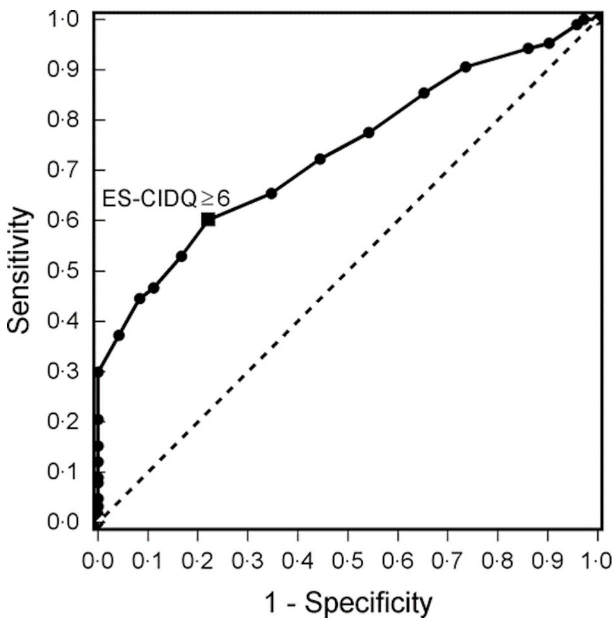

Figure 8. Receiver-operating characteristic curve presenting the ability of the diet quality index to assess a good diet quality among elementary school-aged children. The cut-off point of ≥6 points for good diet quality minimises the Euclidean distance from the upper left corner (– – –, line of no discrimination). From Publication IV.

Nutrient intakes of 10% (27/266, SFA criterion) to 85% (227/266, vitamin C criterion) of the elementary school-aged children adhered to the criteria of a health promoting diet, calculated from the food diaries (Table 26).

Table 26. Elementary school-aged children's adherence to the criteria for health promoting diet (n=266). Modified from Publication IV.

CRITERIA FOR HEALTH-PROMOTING DIET	ADHERENCE TO THE CRITERIA, n (%)
Sucrose (<10 E%)	138 (51.9)
Saturated fatty acids (<10 E%)	27 (10.2)
Dietary fibre (2–3 or ≥3 g/MJ)	90 (33.8)
Vitamin C (≥40 or ≥50 mg/d)	227 (85.3)
Calcium (≥700 or ≥900 mg/d)	181 (68.1)
Zinc (≥7 or ≥8/11 mg/d)	182 (68.4)
Vegetables, fruits and berries (≥250 g/d)	99 (37.2)

E%, percent of energy intake; MJ, megajoule.

5.5.1 Comparisons of energy and nutrient intakes between the diet quality groups

The diet quality was found to be poor (ES-CIDQ score less than six points) in 50.2% (132/263) and good (ES-CIDQ score six points or more) in 49.8% (131/263) of the elementary school-aged children. As the energy intakes were higher among children with good diet quality as compared to those with poor diet quality, the comparisons of nutrient intakes between the groups are presented as energy-adjusted values. Significant differences in the energy-adjusted nutrient intakes were found between the groups (Table 27); children with good diet quality got higher proportions of energy from protein and the lower proportions of energy from sucrose, total fat and SFA. No differences in the intakes of carbohydrates, MUFA and PUFA were found between the diet quality groups. Children with good diet quality had also higher intakes of dietary fibre and various vitamins and minerals as well as a lower intake of dietary cholesterol. Intakes of most nutrients also correlated with the ES-CIDQ score (see details in Publication IV).

Table 27. Differences in the energy-adjusted nutrient intakes between the diet quality categories (poor and good diet quality). Modified from Publication IV.

NUTRIENT	POOR DIET QUALITY (<6 POINTS, n=132‡)	GOOD DIET QUALITY (≥6 POINTS, n=131‡)	P-VALUE
Energy (MJ)	6.2 ± 1.3	6.6 ± 1.4	0.020[a]
Protein (E%)	16.0 ± 2.5	17.2 ± 2.6	<0.001[a]
Carbohydrates (E%)	49.1 ± 5.3	49.5 ± 4.6	0.47[a]
Sucrose (E%)	11.4 ± 4.6	9.4 ± 2.9	<0.001[a]
Fat (E%)	34.3 ± 4.8	32.7 ± 4.7	0.007[a]
SFA (E%)	13.8 ± 2.6	12.7 ± 2.4	<0.001[a]
MUFA (E%)	11.2 (10.0–12.5)	10.8 (9.8–12.4)	0.45[b]
PUFA (E%)	5.2 (4.5–5.9)	5.5 (4.4–6.5)	0.25[b]
Fibre (g/MJ)	2.3 ± 0.6	2.8 ± 0.7	<0.001[a]
Cholesterol (mg/MJ)	28.5 (23.5–36.1)	25.0 (20.6–31.6)	<0.001[b]
Vitamin C (mg/MJ)	11.5 (8.0–16.3)	13.8 (10.5–17.7)	0.002[b]
Vitamin D (µg/MJ)	1.3 ± 0.5	1.5 ± 0.5	0.003[a]
Vitamin E (mg/MJ)	1.0 (0.9–1.1)	1.1 (0.9–1.3)	<0.001[b]
Vitamin A (RE/MJ)	100. 2 (79.1–162.4)	115.9 (87.4–156.8)	0.15[b]
Thiamine (mg/MJ)	0.15 ± 0.03	0.17 ± 0.03	<0.001[a]
Riboflavin (mg/MJ)	0.26 ± 0.07	0.29 ± 0.08	<0.001[a]
Niacin (NE/MJ)	3.6 ± 0.7	3.9 ± 0.7	<0.001[a]
Vitamin B6 (mg/MJ)	0.26 ± 0.05	0.27 ± 0.06	0.038[a]
Vitamin B12 (µg/MJ)	0.67 (0.54–0.83)	0.75 (0.59–0.88)	0.11[b]
Folic acid (µg/MJ)	26.4 (23.5–30.9)	31.1 (25.5–34.7)	<0.001[b]
Pantothenic acid (mg/MJ)	0.66 ± 0.13	0.73 ± 0.17	<0.001[a]
Biotin (µg/MJ)	3.9 ± 1.0	4.5 ± 1.1	<0.001[a]
Calcium (mg/MJ)	143.6 ± 45.1	170.2 ± 49.9	<0.001[b]
Iron (mg/MJ)	1.2 (1.1–1.3)	1.3 (1.2–1.5)	<0.001[b]
Zinc (mg/MJ)	1.4 ± 0.2	1.5 ± 0.2	<0.001[a]
Potassium (mg/MJ)	411.2 ± 73.0	459.7 ± 76.6	<0.001[a]
Magnesium (mg/MJ)	37.8 (33.4–42.2)	42.5 (39.2–47.6)	<0.001[b]
Phosphorus (mg/MJ)	182.1 ± 31.7	206.5 ± 36.2	<0.001[a]
Selenium (µg/MJ)	8.7 ± 1.8	9.1 ± 1.9	0.081[a]
Iodine (µg/MJ)	25.8 ± 6.9	27.9 ± 7.2	0.017[a]

Data presented as mean ± standard deviation or median (lower − upper quartile). E%, percent of energy intake; MJ, megajoule; NE, niacin equivalent; RE, retinol equivalent. [a] Independent samples T-test. [b] Mann-Whitney U test. ‡ Altogether 3 cases answered under 70% of the questions chosen for the index.

5.5.2 Child factors associated with the diet quality

The ES-CIDQ scores or diet quality categories were not associated with the child's sex or overweight/obesity status (Table 28). Moreover, no correlation was found between the children's BMI SDS and ES-CIDQ scores ($r=-0.03$, $p=0.64$). However, the ES-CIDQ scores and categorised diet quality were related to the child's grade in school (Table 28); the younger children (children in grades 1 to 2) had more commonly good diet quality than the older children (children in grades 5 to 6).

Table 28. Differences in the diet quality scores and diet quality categories by sex, school grade and weight status of the children. Modified from Publication IV.

DEMOGRAPHIC FACTORS	TOTAL n	DIET QUALITY SCORE (*n*=263‡)	P-VALUE	DIET QUALITY CATEGORY		P-VALUE
				POOR (<6 POINTS, n=132‡)	GOOD (≥6 POINTS, n=131‡)	
Sex			0.74[a]			0.11[b]
Female	126	6.1 ± 2.7		70 (53.0)	56 (42.8)	
Male	137	6.2 ± 2.7		62 (47.0)	75 (57.3)	
School grade			0.004[c]			<0.001[d]
1st	52	6.6 ± 2.5		21 (15.9)	31 (23.7)	
2nd	56	6.5 ± 2.8		25 (18.9)	31 (23.7)	
3rd	54	5.6 ± 2.9		35 (26.5)	19 (14.5)	
4th	36	7.2 ± 2.3		10 (7.6)	26 (19.9)	
5th	35	5.9 ± 2.4		19 (14.4)	16 (12.2)	
6th	30	4.9 ± 2.5		22 (16.7)	8 (6.1)	
Weight status			0.85[c]			0.36[d]
Underweight	13	5.7 ± 3.5		8 (6.1)	5 (3.8)	
Normal weight	195	6.1 ± 2.7		101 (76.5)	94 (71.8)	
Overweight	42	6.2 ± 2.1		19 (14.4)	23 (17.6)	
Obesity	13	6.7 ± 2.7		4 (3.0)	9 (6.9)	

Data presented as mean ± standard deviation or n (%). [a] Independent samples T-test. [b] Fisher's exact test. [c] Analysis of variance. [d] Chi-squared test. ‡ Altogether 3 cases answered under 70% of the questions chosen for the index.

6 Discussion

6.1 Summary of the results

The studies presented here showed that currently the lifestyle habits of Finnish pregnant women as well as the diet of preschool and elementary school-aged children are suboptimal as compared to the recommendations. Half of the pregnant women had a good diet quality, and the proportions of women consuming vegetables, fruits and berries, fish, fat-free milk and vegetable oil-based spread on bread as recommended were low in both early and late pregnancy. Furthermore, majority of the Finnish pregnant women used vitamin D and folic acid supplements, but the adherence to the recommended doses was low. Only one third of the pregnant women gained weight as recommended during pregnancy and the physical activity levels were low or moderate in majority of the women. No benefits of the enhanced app use were shown on the lifestyle habits. Nonetheless, frequent app users in the enhanced app group had a higher level of physical activity in late pregnancy than those in the standard app group: thus, frequent app use in combination with evidence-based health information delivered via the app might motivate women to maintain the physical activity level as the pregnancy proceeds. Further, physical activity levels among app users decreased less likely compared with app non-users over the course of pregnancy, indicating that the app use may be beneficial in supporting the maintenance of physical activity. The use of the health app exerted no benefits on the diet quality and gestational weight gain. The results also indicated that only one in seven preschool-aged children and half of the elementary school-aged children had good diet quality, which was attributable especially to the low consumption of vegetables, fruits and berries. Child's weight was not associated with the child's diet quality. Instead, the child's younger age was associated with the good diet quality in both preschool and elementary school-aged children. Furthermore, parents' higher education and parents' self-perceived healthy diet were related to good diet quality among the preschool-aged children. The developed stand-alone index, i.e. a tool independent of other dietary assessment methods, depicted diet quality in elementary school-aged children as defined in the dietary recommendations. Thus, it may be used as a valid tool in measuring diet quality in dietary screening in e.g. school health care or nutrition research. The key findings are summarised in Figure 9.

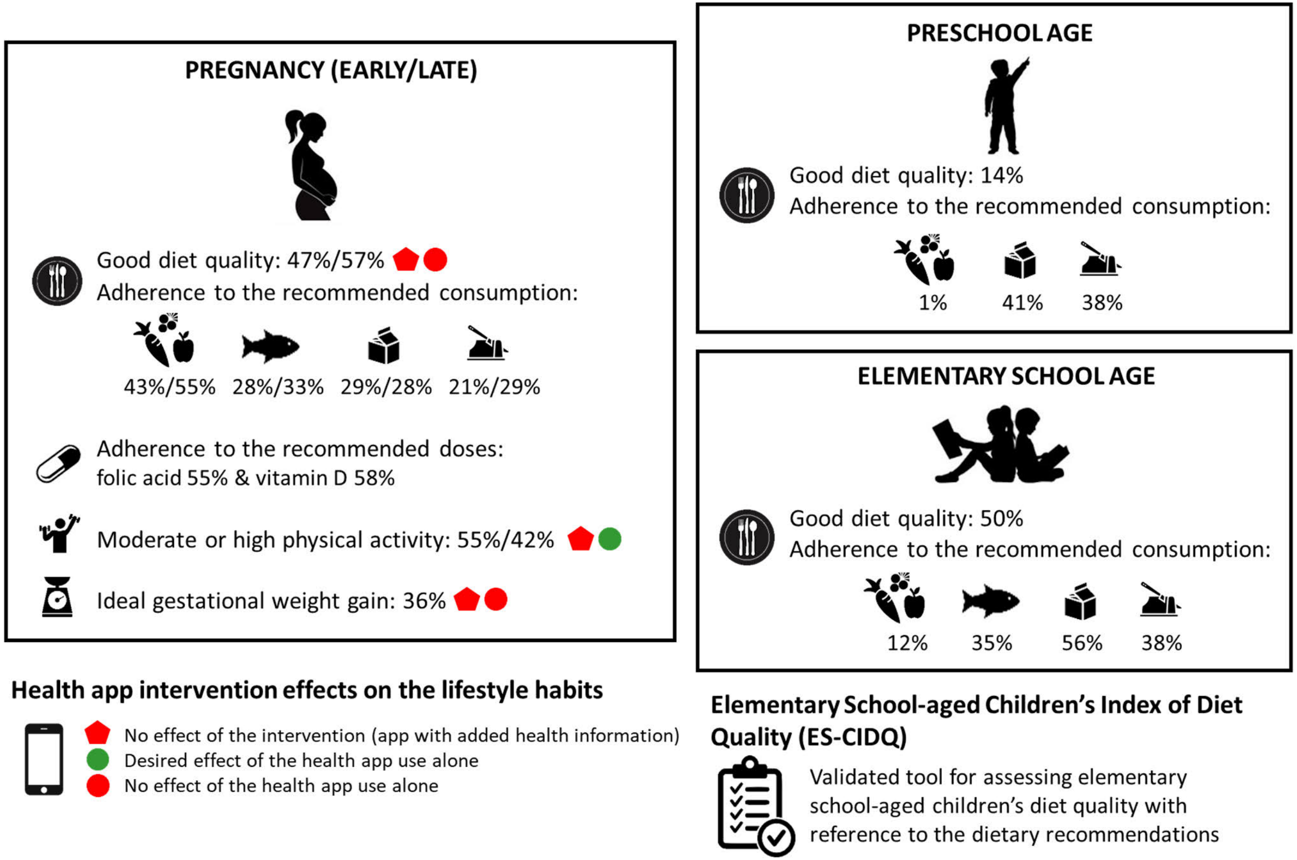

Figure 9. Key findings on the lifestyle habits of Finnish pregnant women and diet of children, the efficacy of the health app intervention and the development of the diet quality index for elementary school-aged children.

6.2 Lifestyle habits of pregnant women

Diet

The results of this thesis offer timely information on the diet in comparison with national dietary recommendations in a large population of pregnant women from different parts of Finland. The findings on the diet quality were in line with the previous studies among Finnish pregnant women; the mean diet quality scores, measured with IDQ, have rarely reached 10 points (the cut-off for good diet quality) [34–36] and around half of the women have had a good diet quality [35,36]. Also, the Finnish studies that used the HFII found that pregnant women scored a bit more than half of the total scores suggesting that the diet quality is not in an optimal level [32,37,44]. As reported here, also other Finnish studies have found that the diet quality has slightly improved over the course of pregnancy [36,37,44]. The reason for this might be that the women want to make positive changes in their diet for the health of the baby or due to e.g. nausea or pregnancy cravings which are often strongest at early pregnancy [295]. The findings of this thesis were also aligned with those from other Western countries as many pregnant women have been reported to have a poor-quality diet. For example, studies with European women that have found that around third of the women or even less have a good diet quality [126,136] or a high adherence to Mediterranean diet [126,139]. Similar findings have been reported in the US and Australia where less than half of the women have a good diet quality during pregnancy [118,119,122]. However, as different diet quality indices with varying scoring methods and cut-off values were used in these studies, the results may not be directly comparable with each other.

The adherence to the recommended consumption of vegetables, fruits and berries at least five portions a day reported in this thesis (43% and 55% in early and late pregnancy, respectively) was higher than that reported in the DIPP study with Finnish women in late pregnancy (24%); however, a lower or similar proportion of women were found to consume vegetables (59−73% vs. 88%) and fruits and berries (54−75% vs. 76%) daily as compared to the previous study [38]. The differing results may be due to e.g. different methods used for dietary assessment: the IDQ method, used in the present study, assesses the food consumption over the previous week, whereas the FFQ method, used in the DIPP study, assessed the food consumption over the 8th pregnancy month and was filled in retrospectively after delivery. The IDQ measures diet for a shorter period of time, and thus might have limitations in measuring the habitual food consumption. However, it is likely to increase the accuracy of our results that the time period for which the individual needs to memorise the food consumption is shorter and immediately prior to filling in the questionnaire. Furthermore, since the index is quick and easy to complete, the participants are likely to be motivated to answer the questions carefully. The findings of the present study are similar to those previously reported in US women of which 30−45% and 45−65% consumed the recommended amount of vegetables and fruits, respectively [119–121]. Even lower adherence to the recommended consumption of vegetables and fruits during pregnancy have been reported in e.g. studies with Croatian [139] and Spanish women [143] as well as in women from Canada [109,132], Australia [141] and New Zealand [144]. Here, too, different methods, e.g. diet quality indices, FFQs and other questionnaires, were used for the dietary assessment, which might partly explain the divergent results. Interestingly, the present study (study II) also found that only one fifth of Italian women reported consuming at least two portions of vegetables per day, which was clearly lower proportion compared to e.g. Finnish women among which the respective proportion was 59%. This discrepancy might be due to differences in food culture, but also to differences in reporting the food consumption e.g. it might be hard to consider what is counted as a vegetable or fruit, e.g. tomato sauce. Furthermore, as the questionnaire assessing the food consumption in the study II did not include examples of vegetables or vegetable dishes, it is also possible that the women did not take into account the consumption of e.g. cooked vegetables, which might also explain the result. Nonetheless, as vegetables, fruits and berries include high levels of vitamins, minerals, fibre and other bioactive compounds and as the high intakes have been linked with many health benefits e.g. lower risk of cardiovascular disease and some cancers [296,297], increasing the consumption of vegetables, fruits and berries to meet the recommended amounts should be encouraged especially during pregnancy.

The results also indicate that only less than third of the Finnish pregnant women used fish at least two times per week as recommended (study I) and around half of the women consumed fish on a weekly basis (study II). These results are similar to the findings reported previously among Finnish pregnant women [38,40] as well as among pregnant women living in Croatia [139] and the US [145], whereas a Spanish study [143] reported even lower consumption of fish (2% consuming fish weekly). It is of note that in the present study, the weekly consumption of fish varied greatly between the four countries, the proportion ranging from 41% of Polish women to 68% of Italian women. Here, too, it should be considered that the dietary assessment method used may impact greatly on the results of fish consumption, e.g. three-day food diary may underestimate the fish consumption due to the limited data collection time compared to the FFQ which assesses the habitual fish consumption over a longer time period. The low consumption of fish among pregnant women may arise e.g. from the fear of potential adverse effects of methylmercury resulting from high fish consumption [298,299]. However, fish is an important dietary source of e.g. omega-3 polyunsaturated fatty acids which are essential for the visual and neurodevelopment of the foetus [300]. Hence, fish consumption during pregnancy should be increased by eating a variety of fish with low mercury levels [300].

To ensure the optimal intake of omega-3 fatty acids, it is also recommended to use e.g. vegetable oil-based spreads with 60−80% of fat on bread. Approximately 21−29% of pregnant women in this thesis used vegetable oil-based spread instead of butter or spread with fat content less than 60%, whereas in the DIPP study 32−54% of Finnish pregnant women were reported to use vegetable oil-based spread [39] and in another study 43% of women used soft margarine with fat content of 60% or more [38]. The results of the current study and the previous ones suggest that the consumption of vegetable oil-based spread instead of other options could be increased among pregnant women.

The pregnant women studied in this thesis had more commonly a regular meal pattern (only around 10% of women had an irregular meal pattern) compared to women in other Western countries in which 13−34% of women were shown to have irregular meal patterns, e.g. they skipped main meals even on a daily basis [116,149,150,301]. Having a regular meal pattern is beneficial for health as it may facilitate e.g. appetite control and weight balance and lower the risk of cardiometabolic consequences in the mother [302,303].

Food supplement use

Findings of this thesis indicate that the vast majority of Finnish pregnant women (98%) and a slightly lower number of women in Italy, Poland and the UK (83−93%) used at least one supplement product during pregnancy, and the most commonly used supplement product was prenatal multivitamin/multimineral supplement (use by 76−91% of women depending on the country). The results are similar to those reported in previous studies with Finnish pregnant women in which the prevalence of using supplements during pregnancy has been 77−96% and the use of multivitamin/multimineral products has been common [35,50–53]. Moreover, studies conducted in other Western countries have found similar results as the prevalence of supplement use has ranged between 65 and 94% of women [52,130,152–162] and several studies have reported that multivitamin/multimineral products were the most commonly used supplements [130,155–158]. Interestingly, the number of supplement products used at a time among the pregnant women differed between the countries in this study. Although it was most common to use only one supplement product at a time in each of the countries, the pregnant women in Finland used up to nine different products simultaneously, whereas in the other countries the maximum number of products used at a time ranged from five to seven. Similar finding on the simultaneous use of high number of supplement products was reported previously among non-pregnant Finnish consumers in a plant food supplement study including consumers from six countries [304]; the reason for the result may relate to e.g. differences in advertising, supplement recommendations or healthcare.

In this thesis, most of the Finnish women using supplements used both folic acid and vitamin D containing supplements, which are recommended to be used during pregnancy in Finland. However, despite the prevalent use, only around half of the women used these supplements with the recommended doses of 400 µg of folic acid and 10 µg of vitamin D. Approximately one third of the women exceeded the recommended doses of both folic acid and vitamin D supplements. There are no previous studies reporting the proportion of Finnish pregnant women adhering to the recommended supplement intakes, but the mean daily intakes of folic acid and vitamin D as supplements have been 57−111 µg [38,51] and 1.2−3.7 µg, respectively, based on the DIPP study data [38,51,54]; these numbers are far from the recommended intakes. The adherence to the recommended intakes of supplements during pregnancy has not been widely reported in the other Western countries, but one study in Canadian women reported that the adherence to the recommended doses of folic acid and vitamin D supplements during all three trimesters was 91−97% and 68−74% respectively, indicating a high adherence to the recommendations especially for the folic acid supplements [156].

In addition to exceeding the recommended dose, 20% of the supplement users in Finland also exceeded the daily safe upper intake limit of at least one nutrient, most commonly that of magnesium, with the respective proportion being 6−25% in the other studied countries. Consuming multiple supplement products at a time and exceeding the recommended doses or even the safe upper intake limits of some nutrients during pregnancy raise concerns as these habits may lead to high daily intakes of certain nutrients, which may be detrimental for health of the mother and the foetus due to potential adverse effects, e.g. teratogenicity of vitamin A [47]. In Finland, prenatal multivitamin/multimineral supplements do not include vitamin A and this was likely to be reflected in the results as only 1% of women reported use of vitamin A supplements. However, every one of ten Italian women used vitamin A containing supplements. Although the participants did not use vitamin A supplements above the daily safe upper intake limit, it is important to be aware of the risks related to vitamin A. Furthermore, exceeding the daily safe upper intake limit of magnesium may cause mild adverse effects, e.g. diarrhoea, but also severe adverse effects, e.g. hypotension or muscular weakness, may be presented with very high doses [305]. Overall, the results suggest that many pregnant women in Finland and in other Western countries might not be aware of the supplement recommendations and safe doses. Hence, it is essential to raise the awareness of the recommended doses and limitations of supplements during pregnancy.

Physical activity

Findings on the physical activity during pregnancy suggest that majority of pregnant women had low physical activity level during pregnancy and that the level of physical activity decreased as the pregnancy proceeded. These findings are similar to those of previous studies with Finnish pregnant women in which low physical activity compared to the recommendations have been reported in a high number of pregnant women [37,44,59,60] and a decrease in the physical activity over the course of pregnancy has been observed [50,61,63]. The observed findings seem to be typical to pregnant women also in other Western countries: 5−46% of pregnant women adhered to the recommended physical activity level of at least 150 minutes of moderate to vigorous physical activity in e.g. Italy, Spain, the Netherlands and the US [167,169,170,177,178]. The findings underline that despite the comprehensive maternal health clinic system in Finland, within which promoting the healthy lifestyle habits to all attending women is in the planned protocol of the health clinic visits, the level of physical activity is commonly low already in the early pregnancy and it further decreases as the pregnancy proceeds despite the proven benefits of physical activity. This may be due to numerous barriers related to pregnancy itself, e.g. pregnancy-related symptoms such as pelvic girdle pain, but also for e.g. time constraints, lack of motivation and safety concerns [64,177]. It is important to find new ways to motivate pregnant women to increase their physical activity levels despite these barriers.

Gestational weight gain

The findings of this thesis indicate that only one third of the women gained gestational weight as recommended by the IOM and similarly around one third gained excess amount of gestational weight. Further, the women with overweight or obesity were more prone to have higher than recommended GWG as compared to the women with underweight or normal weight (49% vs. 25%, respectively). The mean total GWG of 12 kg reported in the present study is comparable to those found in previous Finnish studies with a GWG range of 9 to 15 kg [34,39,50,51,72–75]. Also, the proportion of women gaining the ideal amount of gestational weight was similar to those reported by previous studies in Finland, e.g. in a study with healthy primiparous women, approximately one third of the women had excess GWG [75], whereas in the NELLI study over half of the women with increased GDM risk gained gestational weight in excess [74]. In the FOPP study including women with overweight and obesity, the proportion of women with excess GWG was even higher than in the present study with around two out of three women gaining excess weight during pregnancy [36,72]. In addition, the results reported in this thesis are similar or even more favourable as compared to the recommendations than those reported in e.g. Sweden, Italy, Greece, Ireland, New Zealand, Australia and the US, in which 17−40% of pregnant women had ideal GWG [179–185,187,188]. Also, the proportion of women with overweight or obesity having excess GWG has been high (34−84%) in Western countries [178,179,183,185,186,188,190,193,194], in some cases even notably higher than in this thesis. Although women with overweight and obesity might get special instructions regarding diet and physical activity from the maternal health care, this was not shown in the results. However, women with overweight and especially those with obesity have strict recommendations for GWG as they have an increased risk for pregnancy complications; therefore, adhering to the recommended GWG might be more difficult for them compared to their counterparts with underweight or normal weight. It is also of note that in the present study, the weight was self-reported by the women and the gestational weeks when they filled in the late pregnancy questionnaire ranged from 33 to 40. As many women may gain a considerable proportion of the gestational weight during the third trimester of pregnancy, the actual GWG might have been somewhat higher in those women who filled in the late pregnancy questionnaire several weeks before the delivery. This issue should be acknowledged as one limitation of the study.

6.3 Efficacy of the health app in behaviour change

Characterisation of app use and users

Overall, the use of the app remained low among the participants: merely one-third of the participants made recordings in the app and the median duration of app use was less than five weeks. This finding was somewhat surprising as it was anticipated that pregnancy would serve as a period of increased motivation for self-monitoring of lifestyle habits. Self-monitoring is a method for behaviour change, derived from a social cognitive theory of self-regulation [306], which has been widely used in health apps [307–309]. However, some previous studies have also shown low overall health app usage during pregnancy [151,260]. As also reported in previous studies [310], technical challenges may have deterred the use of the app for some participants in the present study, although many others reported no such challenges with the app (Supplementary Table 5). Half of the participants also reported that the use of the app was difficult (Supplementary Table 5), which might be one reason for the app abandonment. It has been shown that app users typically devote a maximum of 30 seconds to learn how to use the app before abandoning it [311]. In fact, user-friendliness is likely to be one of the key factors affecting the acceptance of the health apps [311,312]. Women who were interested in joining the study may have already been using another health app and were reluctant to use both or switch to the app provided in this study. It has been estimated previously that individuals who use health apps have three such apps on their smartphones, but they typically only use two of them [313]. One explanation for the low app use in the present study may therefore be that as the app did not include pregnancy-related features, such as tracking one's gestational weeks or general information on the growth of the foetus in given gestational weeks, the participants may have had another pregnancy app for this kind of features. Some successful app-based intervention studies have also included goal setting features [151,264,278], which might be beneficial in behaviour change. The goal setting theory suggests that setting specific, demanding goals in health behaviour change and maintenance interventions may lead to better results than with no goals or unspecified goals [314]. However, if the individual is sceptical about the effectiveness of the health app use while also lacking persistence to reach the goals, the individual might abandon the app use [315]. Overall, app features and the potential for high user engagement have been recognised to affect the long-term use of health apps [316], but determining the essential and engaging features remains uncertain as it appears to be a subjective matter. For example, gamification of the health app might improve the user engagement [317]. The insights obtained from this study may facilitate the development of more user-friendly and enjoyable apps for pregnant women, thereby also enhancing their effectiveness in supporting healthy lifestyle.

As the lifestyle habits of many pregnant women clearly need improvement, it would be beneficial to engage in the health app use and self-monitoring especially those women with lower education and less healthy lifestyle habits who would be more in need of lifestyle changes and might have limited knowledge of what represents a healthy lifestyle [318]. However, the findings of the present study indicate that women with high education, underweight/normal weight and a non-smoking habit were more likely to use the health app as compared with their counterparts with a lower education and less healthy lifestyle habits. Ambiguous findings on the association between weight and health app use have previously been reported in a non-pregnant population: a lower BMI value was associated with more frequent health app use [319], whereas others reported opposite findings [320] or no link between weight and health app use [321]. Other results of this thesis are consistent with previous findings in a non-pregnant population as e.g. higher educational level [313,321,322] and being married [323] have been linked to health app use. Further, primiparity has also been linked with higher app user engagement [324], probably due to the enthusiasm, information-seeking attitude and better time resources of primiparous women as compared with their multiparous counterparts. However, there are only limited information available on the characteristics of the typical pregnant health app user, and thus further research on the topic in warranted to understand how to better engage those women in need of lifestyle changes the most. It should also be noted that using health apps in the health care practice may not be suitable for everyone as some individuals consider that communication with health care professionals may be ineffective via health apps and the apps might lack e.g. personal touch and empathy, which can lead to app abandonment over time [325]. Furthermore, the app use requires digital literacy from the patients and the health care professionals [325]. In Finland, this is likely not an issue, as it has been estimated that almost every person (97−100%) in the 16- to 44-year-old age range possesses a smartphone [256]. Thus, health apps may serve as efficient tools in the health care practice if both the patient and the health care professional are willing and capable to use the method.

Effects of the app use frequency on the lifestyle habits

The health app exerted some benefits on the lifestyle habits during pregnancy. The proportion of women with moderate or vigorous physical activity was found to decrease less among app users in comparison to app non-users during pregnancy suggesting that self-monitoring of physical activity with the health app may motivate women to sustain their exercise routines also in the later stages of pregnancy. Similar findings have been reported in a Canadian health app intervention study which resulted in higher physical activity levels in pregnant women in a higher app use group; however, the number of participants was small (n=27) [262]. As it has been shown in this thesis and previously that the amount and intensity of physical activity tend to decline throughout pregnancy, these results are of relevance due to the proven benefits of physical activity on health in general, but also since maintaining physical activity over the course of pregnancy has been associated with lower risk of pregnancy complications [56].

Unfortunately, frequent app use did not affect the overall diet quality although the app included many diet-related recording types and numerous participants were monitoring their diet profoundly: the diet-related recording types, such as daily meals and consumption of vegetables and fruits, were the most frequently used recording types. Despite the disappointing result, there may still be some impact of the app use on the separate diet quality components, considering that frequent app users were more likely to be eating fruits and/or berries every day compared to occasional app users or app non-users in late pregnancy. No effect was detected on the gestational weight gain either. One explanation for this can be that the participants made only limited recordings of their weight in the app, merely 2% of all the recorded data. It is possible that most of the women did not deem necessary to consistently monitor their weight during pregnancy since gestational weight gain is regularly followed in maternity clinics in Finland. Moreover, monitoring the weight gain during pregnancy may be stressful for some mothers [326]. Another reason could be that the shown effect of maintaining the physical activity alone, as no effects were seen on the overall diet, might not be enough to exert benefits on the weight gain since excess weight gain is expected to, at least partly, result from imbalance between energy intake and expenditure.

Pilot intervention effects on the lifestyle habits

To the best of my knowledge, this is the first attempt to investigate whether evidence-based health information delivered solely via a health app, without face-to-face consultation, could inspire pregnant women to adopt health-promoting lifestyle. It is common practice in intervention studies that health information is delivered face-to-face by a health care professional, e.g. during health clinic visit or in combination with an app or other online method [151,260,275,276]. Since online interventions could offer similar efficacy while being more readily accessible and cost-efficient than conventional approaches [257,258], the purpose of the present study was to investigate the effects of an online-only intervention. Further, it was anticipated that regularly providing simple key messages regarding health-promoting lifestyle and how it would prevent pregnancy-related health risks would motivate the women to alter their health behaviour during pregnancy. This presumption is in accordance with e.g. the health belief model, in which it has been hypothesised that certain factors need to be present simultaneously when trying to change one's behaviour: the motivation for change, the belief that one is personally susceptible to the health risk and the belief that the risk can be alleviated by taking action [327,328]. Nevertheless, this pilot intervention exerted no effects on the lifestyle habits during pregnancy. Although the dropout rate was higher than anticipated, the small and clinically insignificant differences between the groups would suggest that the results are unlikely to be affected in a larger study population. It is still important to note that frequent app users in the enhanced app group had a higher level of physical activity in late pregnancy compared with frequent app users in the standard app group. This suggests that, although the number of women was smaller in these analyses (n=193), a combination of frequent app use with additional evidence-based health information delivered via the app might still be advantageous in motivating the women in maintaining the physical activity level during pregnancy. However, more research on this issue with a larger number of participants is still needed, while also taking into account that improving the usability of the health app might also increase the efficacy of the app.

There were a number of potential explanations why the intervention did not achieve the expected results. It could be that the intervention messages should have been sent to the participants more frequently than once a week. Even daily contact with the participants have been reported previously [275,329,330], but also only monthly contacts have been maintained in some online interventions [331].

Delivering information on physical activity to pregnant women on a daily basis may actually even discourage them from engaging in physical activity [332]. While these studies were not only app-based interventions, the findings also nevertheless suggest that the rate of intervention messages employed in the present study was deemed acceptable. It could still be speculated whether delivering lifestyle information to the participants two to three times a week would have exerted more benefits. Furthermore, the intervention messages were not tailored to each participant's individual needs. As highly personalised interventions have been proposed to be more effective than non-personalised ones [333], the intervention might have been more effective with personalised messaging and feedback, created e.g. by machine learning, in order to improve the participants' engagement with the intervention and possibly mitigate the high dropout rate observed in the study. Since the intervention messages were delivered via the app and, in general, the adherence to self-monitoring and using health apps have been observed to decrease gradually, more regular reminders to use the app, e.g. via text-messages or e-mails, might have increased the women's adherence to the intervention [334]. However, as one of the study aims was to investigate the health app use among pregnant women, this approach was not taken. It has been shown previously that the dropout rates might be high if the intervention is delivered without face-to-face contact to the participants [331,335–337]; yet, implementing lifestyle changes during pregnancy has been challenging even in those intervention studies that provide personalised face-to-face counselling to the participants [37,338]. Lastly, it is intriguing to note that frequent app users in the enhanced app group reported attempting to enhance their overall eating habits as presented in the Publication I; however, this did not result in actual alterations to their dietary habits.

6.4 Children's diet and associated demographic factors

Diet in preschool-aged children

The diet was not in accordance with the recommendations in most of the preschool-aged children with mean diet quality scores of 11 out of the maximum score of 18 points and only 14% of children having good diet quality. The scores reflect the previous findings of the STEPS study conducted in Finnish preschool-aged children in which the mean diet quality scores were slightly higher than half of the maximum scores, e.g. 6 out of the maximum score of 10 points [86]. Low diet quality scores have also been common in other Western countries: in many studies children only achieved on average 50−60% of the maximum scores measured with a diet quality index [94,198,201–203,208,210,212,216]. In the US and Greece, even lower proportion of children (0.4−11%) had good diet quality as measured with HEI [198,209]. On the other hand, some studies have demonstrated better diet quality among preschool-aged children from Croatia, Cyprus, Italy, Germany, Spain, Hungary, Estonia, Belgium, Sweden and Norway with 24−74% of the children having high adherence to MD [207,216–219]. However, it is vital to note that each of the diet quality indices used in the studies have different cut-off values for good and poor diet quality or high and low adherence to the recommended diet. Therefore, comparing the results between the studies might be spurious.

Worryingly, less than half of the children in the present study consumed vegetables and fruits daily and only five percent consumed berries daily. These results were further reflected in that only a very small proportion (1%) of the children met the recommended consumption of five portions of vegetables, fruits and/or berries a day. This is notably lower than in the STEPS study conducted in Southwest Finland, in which around half of the participating children met the recommended consumption [86]. One reason for the differing results may lay in the different dietary assessment methods: the questionnaire used in the STEPS study is a modified version of the IDQ which has not been validated in children, whereas the CIDQ used in our study has been developed and validated particularly for this age group of Finnish children. It should also be taken into consideration when interpreting the results that both of these methods rely on the memory and estimation of the parents, which might affect the results in general since e.g. the parents often don’t know in detail what their children have eaten outside the home [80,81]. However, the results of this thesis were more alike to those reported in another study with Finnish preschool-aged children in which around two out of three children consumed fresh vegetables and half of them consumed fresh fruits on a daily basis, but only 7% consumed berries daily [7]. The reported consumption of vegetables and fruits in other Western countries has mostly been higher than that reported here, although the results vary greatly between the studies. In the US, 6−46% of the children have been reported to meet the recommended intake for vegetables and 34−50% for fruits [209,220,221], whereas in Canada, up to 73% of children met the recommendation for vegetables and fruits per day [202]. In other countries, the daily intake of vegetables and fruits has also been higher than found in this thesis: more than two out of three US children consumed vegetables and fruits on a daily basis [221], and almost all (94%) Croatian children consumed fruits or fruit juice and up to 78% consumed vegetables daily [218]. The consumption of berries among children has not been widely reported in other Western countries.

Results of the present study regarding the consumption of vegetable oil-based spread on bread (38% chose this option instead of butter or butter-vegetable oil mix) also reflect the results of the previous studies in Finnish children, where one third of the children consumed vegetable oil-based spread with fat content of more than 60%

[86] or around half of the children consumed margarine with fat content of at least 55% [89]. Likewise, the results of this thesis on the proportion of children consuming fat-free milk (41%) align with the previous studies demonstrating that around half of the children in this age group have consumed fat-free milk [7,89]. These numbers are higher than reported e.g. in US preschool-aged children of which only 22% were found to consume milk with at least 1% of fat [222].

Diet in elementary school-aged children

Findings of this thesis indicate that half of the elementary school-aged children had a good diet quality as measured with the ES-CIDQ. There are no previous studies reporting the proportions of Finnish elementary school-aged children with good or poor diet quality. However, previous studies with 6−8-year-old Finnish children have reported e.g. mean Baltic Sea Diet, MDS and FCHEI scores being equal to or less than half of the maximum scores of the indices [99,101]. This indicates that, on average, the quality of diet in this age group of Finnish children is not in an optimal level. This does seem to be a common finding among children also in other Western countries. In US children, the mean HEI scores have ranged between 42 to 54 points from the maximum score of 100 points [94,95,233], whereas British children got on average 9 point out of the maximum score of 16 points from DQI index [232]. Even lower scores have been demonstrated in Australian and Irish schoolchildren with the former getting on average 25 points from the maximum score of 73 from ACARFS index [231] and the latter scoring on average 9.5 points out of the maximum of 25 points from DQS index [230]. Furthermore, similar or even higher proportion of Finnish children had a good-quality diet as compared to children in other Western countries. In Canada, only every fifth elementary school-aged child had a good diet quality according to the HEIC-2009 [226], whereas 26–49 % of Spanish and Greek children were reported to have a good diet quality as measured by the KIDMED index [138,243,244]. Moreover, only 3.5–5 % of Cretan, Portuguese and Italian children have had a good diet quality as measured by the KIDMED or the HEI [197,240,241]. Some studies, however, reported even higher proportion of children with optimal diet quality as measured by the KIDMED: 56–58% of Spanish [237,242] and 78% of Portuguese elementary school-aged children [239].

The daily consumption of vegetables (51%), fruits (33%) and berries (3%) was found to be low among the Finnish elementary school-aged children and only 12% of them met the daily recommendation of five portions of vegetables, fruits and berries. These results are well aligned with the previous studies with Finnish school-aged children, which have demonstrated that only one out of three children consumed vegetables or fruits on a daily basis [6] and less than five percent of 6–8-year-olds met the daily recommendation [5]. Similarly, low consumption of vegetables and fruits has been common also in other Western countries in this age group. In an Italian study, less than 3% of children consumed vegetables and 31% consumed fruits as recommended [234] and in the Netherlands, 16% of children consumed vegetables and 29% consumed fruits according to the recommendations [235]. Likewise, 20% of US children consumed fruits and 40% consumed vegetables as per the guidelines [228], whereas less than 20% of Canadian children consumed vegetables and fruits as advised [245]. On the other hand, two other Canadian studies, both from the same STEAM study data, reported up to 48−60% of children consuming the recommended amount [247,248].

Half of the Finnish elementary school-aged children in the present study consumed fat-free milk, which is a somewhat lower proportion than previously reported (63–67%) among Finnish children of the age group in the PANIC study [5]. The finding is in accordance with that of a Swedish study reporting less than half of children consuming low-fat milk daily [246], but notably higher than that of a US study demonstrating only one-fifth of children consuming low-fat milk [251]. The differing results might be partly explained by different food culture and dietary recommendations, but also by different dietary assessment methods. For example, in the US study, the milk consumption was inquired on a monthly level [251], whereas in the present study, the milk consumption was inquired over the preceding week. Although our results might not represent the habitual consumption as well due to the shorter dietary assessment period, it may enable a better estimation of the food consumption as it does not require as much memorising. In the US study [251], the children also reported their food consumption themselves which may impact the results as children's skills in recalling their food intake and estimating portions sizes are limited, which together with other factors, such as child's unstructured eating patterns, concerns of self-image and rebellion against authority particularly among children in puberty, may lead to misreporting [80,81]. In the present study, the children fulfilled the FFQ together with their parents, which may enhance the accuracy of the dietary report if the child was motivated in reporting what she/he has eaten. Moreover, parents alone might not be able to report their child's diet as well since they might not know in detail what the child has eaten outside home and during the school days [80,81].

One third of the Finnish children in the study reported in this thesis consumed fish at least twice a week; this is also a slightly lower proportion than previously reported (42–44%) in Finland [5]. The results are also comparable to other countries: in the Mediterranean area, 24−64% of children consumed fish at least twice a week [138,218,240,253], whereas in Sweden, up to 84% of children consumed fish at least once a week [246]. Furthermore, less than 40% of children in the present thesis consumed vegetable oil-based spread with at least 60% of fat on bread which is notably lower than reported previously in Finnish children (67−74%), although in the previous study, the result included all margarines with a maximum of 70% of fat [5]. Most of the children also had a regular eating frequency during weekdays (85%) and weekend days (73%), which aligns with previous findings of this age group in Finland with 76% of children having regular eating frequency [6].

In the present study, almost half of the elementary school-aged children adhered to the healthier dietary pattern (as opposed to the unhealthier pattern) characterised by high consumption of e.g. vegetables, fruits and berries, whole grain and fish, reflecting the previously discussed results. A similar pattern with high consumption of e.g. vegetables, fruits, berries and dark grain bread was found previously in a larger study with 9−14-year-old Finnish children; here too, 44% of the children adhered to the pattern [6]. In a large cross-national study with 12 countries including Finland, the investigators also found a similar pattern with higher loadings for e.g. vegetables fruits and berries [100]. These findings indicate that dietary pattern reflecting the recommended diet is typical for some children in Finland, but not others.

Demographic factors related to child diet quality

The findings of this thesis highlight a need for increased efforts to improve the quality of children's diets in Finland, e.g. by providing enhanced lifestyle counselling to the families within child health clinic and school health care settings. The whole family should be targeted as the diets of children are likely to be influenced by their parents' own dietary habits [339–341] as they are responsible for offering food to the family and are often present during family mealtimes. As parents may have limited understanding of the connection between their child's diet and her/his long-term health [342,343], it is important to engage and support parents in providing healthier dietary practices for their children already in the preschool and elementary school-age. Understanding the factors associated with child's diet quality may help in enhancing the lifestyle counselling of the families in the health care setting.

Unexpectedly, the children's overweight/obesity status did not show any association with the quality of diet either in preschool or elementary school-aged children. Previous research has demonstrated that following dietary guidelines in childhood may protect individuals against obesity risk factors [344] and better diet quality has been linked with children's lower weight and BMI [216,230,232]. However, some studies have found no connection between these factors among children [197,209,214,218,240]; instead, an association between diet quality and body fat of children has been demonstrated in both preschool and elementary school-aged children [255]. In fact, it has been suggested that measuring body fat may help in identifying children with overweight or obesity more precisely compared to weight or BMI as it may be challenging to identify children with normal weight with excess adiposity [345]. One reason for the unexpected findings in the present study might be that since neither of the diet quality indices do not take into account the intakes of energy, it may be that, although the quality of diet was similar among the children, children with overweight have higher energy intakes than their counterparts with normal weight [346], which might be the primary cause for the excessive weight. The indices do not assess the consumption of e.g. various high-energy snacks, since these food items were not found pertinent for overall diet quality in the index validation processes due to pervasive use of snacks by children. Hence, if the children with overweight make as much recommended food choices, but in addition consume more high-energy snacks than their counterparts with normal weight, the indices might not recognise this. Another possible explanation could be that the impact of a poor-quality diet on weight may not yet emerge at a young age as the evidence of the association between diet quality and children's weight, BMI and/or adiposity is largerly contradictory in evaluation of previous studies [197,201,209,214,216,218,230,232,240,255]. Moreover, the cross-sectional study design in both studies does not allow for an assessment of the influence of diet quality on the development of obesity. Therefore, longitudinal research should be implemented to explore the impact of diet on child's obesity and especially body fat, which is not routinely evaluated in child health clinic setting in Finland. It should also be noted that, as measured with the ES-CIDQ, the children with good diet quality had higher energy intake compared to those with poor diet quality. Thus, the energy intake may be a confounding factor as it is possible that children who eat more also get higher scores from the index. However, a high-energy diet does not automatically equal to high index scores as e.g. the consumption of full-milk, as opposed to the consumption of low-fat milk, would have yielded lower scores, but obviously higher energy intake. The energy intake has been taken into consideration in some diet quality indices, such as the HEI [104] and the MDS [98], but as the assessment of energy intake requires the use of another dietary assessment method, this approach is not possible when developing stand-alone indices, such as ES-CIDQ.

Child's younger age was associated with better diet quality in both preschool and elementary school-aged children, as also reported earlier in Finland [86] and in other Western countries [93–95,203,218]. As children grow older, they often become more independent in selecting the foods they eat, which may lead to a lower diet quality. However, some studies have also found opposite results [198,231]; thus, other unknown factors may also affect this phenomenon.

No differences were found in the diet quality between girls and boys in both age groups, which is in line with many previous findings in Finland [86,87] and internationally [93,94,197,202,207,214,218,232,236,240,244], although some studies both from Finland [101] and abroad [138,211,216,217,231] have stated that girls may have better diet quality than boys. Interestingly, although no differences between the sexes were shown in the diet quality in elementary school-aged children, the findings of this thesis indicate that boys were more likely to adhere to the healthier dietary pattern. Some investigators have also found a link between better diet quality and male sex [198,201], but this issue demands further investigation as there is more evidence that the diet quality is better in girls than in boys [138,211,216,217,231]. In Finnish adults, the quality of women's diet has been closer to the recommendations than that of men [3] indicating that the differences between the sexes in diet may arise later in life.

As also found in this thesis, a link between high parental education and good diet quality in their children has been well established [86,87,93,198,202,203,207, 209,216,232,234,235,240,244,255]. This might be due to the observation that parents with a low education level may have limited understanding of the importance of healthy nutrition [318,347], which may further limit the healthy food choices they offer to their children. Furthermore, parents with a low education level may have lower resources, e.g. low income level, which might also limit their ability to offer healthy foods to their children [348,349]. They may also be living in socioeconomically disadvantaged neighbourhoods, which has been related to lower diet quality in children [86] due to e.g. lower availability of healthy foods [350,351]. Furthermore, this thesis suggests that the small children had better diet quality if their parents reported that they themselves were following a healthy diet. Parents with a healthy diet often provide their children healthy food choices and children may also have similar food preferences as their parents [352,353]. Parents may influence their child's eating behaviour through parental role modelling so that children adopt their parents' eating behaviour and attitudes towards foods [354–356]. Indeed, an example of healthy eating by mothers has previously been linked to a better diet quality in small children [205,216]. This again suggests that dietary counselling should be directed toward the whole family instead of the child alone [357].

Interestingly, the child's adherence to the healthier dietary pattern was associated with living in Eastern Finland as opposed to Southwest Finland. It is known that dietary intake of adults differs in the eastern and western parts of the country [3], which might also affect the diet in children, but this observation requires further scientific evidence to back up any conclusions as the studies in adults are inconclusive on whether the dietary habits have been healthier in eastern or western parts of the country [3,358].

6.5 Development of the diet quality index

During the index development process, fifteen questions best reflecting the diet quality among elementary school-aged children were identified. The questions chosen for the index inquired about the consumption of foods typically recognised as components of a health-promoting diet, namely vegetables, fruits and berries, low-fat dairy, whole-grain products, fish and nuts [359–361], but also those considered as potential components of an unhealthy diet (e.g. sugary beverages). The results indicated that the consumption of vegetables, fruits and berries were particularly important components of high-quality diet, a finding also demonstrated in previous studies [212,362,363]. Since a regular eating frequency and the consumption of healthy snacks between main meals are also important for the child's health-promoting diet [364,365] and as dietary habits may often be less healthy during weekends than in weekdays [366,367], the questions inquiring these aspects of diet were included in the logistic regression analyses despite non-significant correlations in the previous phase. In fact, these variables were shown to explain good diet quality in the analyses, even though their role in the index was less significant than that of e.g. vegetables, fruits and berries. This was taken into account in the scoring of the index as the most significant questions were scored with higher points and vice versa. Furthermore, the intake of SFA in childhood is a well-known indicator of a healthy diet and it has proven impacts on e.g. cardiovascular health [368,369]. Indeed, the food sources of SFA were linked to the child's health-promoting diet since several FFQ questions assessing e.g. the fat percent of milk, cheese and spread consumed were relevant contributors to the SFA intake and were ultimately included in the index. The SFA intake was higher in children with a poor diet quality than their counterparts with a good diet quality, which further highlights its importance for the child's diet. In addition to low intakes of SFA, also an optimal intake of unsaturated fatty acids is recommended for child's better health [29]. However, many foods with unsaturated fatty acids contain also SFA; thus, it is difficult to identify which foods would be indicators of good or poor diet if the distinction would be only based on the intakes of MUFA and PUFA. Hence, after careful consideration, the intakes of MUFA and PUFA were decided to be omitted from the criteria of a health-promoting diet early on in the process. It is of note that the process of choosing the criteria of a health-promoting diet included decisions made by the researchers, which is one potential source of uncertainty in this study, although the decision-making was backed up by literature and statistical analyses. It may be, for example, that the final index would have included other questions if a different set of criteria had been chosen. However, the key nutrients for children's healthy diet were primarily chosen as the criteria. As an exception, the intake of vegetables, fruits and berries was also decided to be included in the criteria list as they are considered highly important components of a healthy diet [370].

When evaluating the validity of the ES-CIDQ, ROC analysis was used to assess the sensitivity, specificity and accuracy of the index in identifying the children with a poor and good diet quality. The estimated values for sensitivity (0.60) and specificity (0.78) were aligned with the findings of previous studies in which sensitivity values of 0.59–0.67 and specificity values of 0.71–0.82 have been reported [31,282,371,372] and the area under the ROC curve for the good diet quality (0.74) was found to be acceptable [286] indicating that the index distinguishes children with poor and good diet quality with acceptable accuracy. The repeatability analyses were not conducted in the index development process due to the cross-sectional nature of the study, and thus it cannot be evaluated here whether the tool produces consistent measures when used repeatedly. It was also shown that the energy-adjusted intakes of several macronutrients (protein, dietary fibre, sucrose, total fat and SFA) and most micronutrients (e.g. vitamin D and C, iron, calcium and magnesium) were more favourable in children with a good quality diet as compared to their counterparts with a poor-quality diet. Thus, the ES-CIDQ is considered a feasible tool for assessing the child's diet quality in relation to the dietary recommendations. During the statistical analyses, the intention was to categorise the diet quality into three groups to obtain more comprehensive insights into the children's adherence to the dietary recommendations. However, the categorisation into three groups was not possible as the categories overlapped inadequately, i.e. did not separate children well enough, and as the approach diminished statistical power. Thus, a two-category index was created, and it demonstrated a particular specificity in identifying children with a poor diet quality. This was considered vital if the index would be used in clinical practice and school health care since it may be used in screening the children most in need of nutrition counselling. The index can serve as a tool for helping the health care professionals to identify the children in need of dietary counselling and to start a conversation about nutritional issues with the families. Although the ES-CIDQ did not distinguish the children with overweight or obesity, it is still a valid tool for identifying children with poor diet quality, which may increase the risk for obesity [373,374]. In a research setting, in which the diet quality is measured in a population level, the continuous index score is a feasible way of assessing the overall diet quality, while the data could also be categorised in other ways, such as dividing the data into quartiles or other quantiles; this approach could be used in studies with large sample sizes as demonstrated with other indices e.g. the FCHEI [87].

Along with the index developed within this thesis, there are only a few other diet quality indices for children that do not require nutrient intake calculations by using another diet assessment tool, i.e. stand-alone diet quality indices. These include the index previously developed and validated for the assessment of diet quality in Finnish preschool-aged children (used in the study III) [282], the indices developed for 2–5-year-old and 9–12-year-old children in Australia [231,281] and the KIDMED developed and validated for children and adolescents for the assessment of adherence to MD in Spain [206]. The KIDMED has been widely used in the

Mediterranean region over the years, although it still remains uncertain if the index is valid for use in all the other countries in addition to Spain. Although the ES-CIDQ was primarily developed for use in the Finnish food culture, it might also be suitable for use in other European, particularly Northern European, countries with similar diet cultures. However, the possibility to expand the use of the index in other countries, as has been done with e.g. the KIDMED, will need further investigation.

6.6 Strengths and limitations

The strengths of the studies of this thesis include e.g. the relatively large and/or representative study samples in all of the studies and the randomised controlled study design in the study I. The samples of Finnish pregnant women in the studies I and II were representative of Finnish pregnant women with regard to age, pre-pregnancy BMI, being married and locality (study I), but the samples included a slightly higher proportions of primiparous women as compared to the Finnish perinatal statistics [17]. Such comprehensive perinatal data is not available in the other countries included in the study II. Also, the samples of children (studies III and IV) were representative of the age groups with regard to sex and weight. The data for preschool-aged children (study III) were collected by trained nurses thus providing accurate growth data, and the sample was recruited from across Finland with 21 hospital districts out of the total of 23 hospital districts in the mainland Finland being represented. To increase the representativeness of the sample of elementary school-aged children (study IV) and to better reflect the diet of Finnish children, the children were recruited from Southwest and Eastern Finland, since dietary intakes of adults in the eastern and western parts of the country are known to differ [3]. As a potential limitation of the studies, the proportion of participants or the parents of participating children who had a university level degree was generally higher than the national average of 33% of adults in Finland and in the other studied countries (19–36%, study II) [375], which might limit the generalisability of the findings among families with a lower socio-economic status. Participants of the studies I and II were recruited via social media, which has shown to be an effective recruitment method in observational studies [376], particularly when recruiting young females and hard-to-reach populations [377]. Using social media as a recruitment channel may also be a potential source of bias if the participants are more likely to use smartphones, and thus also health apps (study I) or to gain supplement-related information (study II). Here, these worries may not be relevant as vast majority (97−100%) of Finnish adults in child-bearing age possess smartphones [256] and in the study II, only few women reported that social media was an important source of supplement information for them (see the Publication II). As a further strength, the participants of the study II were recruited in four geographically and socioeconomically diverse European countries, which allowed for the investigation of country differences. However, it should be considered as a limitation that the recruitment in the UK was not as successful as in the other countries and the use of additional recruitment methods were needed. Thus, the sample size in the UK was smaller and the study population might not be as representative of pregnant women population as in the other countries. Nevertheless, the UK data was considered valuable to be reported as overall, the data included unique data on daily supplement intake calculated from the packages. It should also be noted that most of the recruited women were using and/or were interested in food supplements and the non-user group was rather small. However, the prevalence of supplement use was aligned with previous studies, which were mostly part of cohort or clinical studies not particularly designed to assess the supplement use [50,52,156,157,159,160].

It is also considered as a strength that the intervention (study I) was based on evidence-based information on health-promoting lifestyle derived from national recommendations on diet, physical activity and gestational weight gain. Furthermore, validated indices were used, when possible, to assess the lifestyle habits of the participants; the IDQ and MET index in the study I and the CIDQ in the study III. However, the validity of the diet quality indices as stand-alone tools has not been further confirmed by testing them against some other dietary assessment method with another study population after their development and validation. This further validation would be a good practice but is not often carried out due to lack of resources. In the study II, despite not using previously developed or validated questionnaires, appropriate measures were implemented in preparing the study questionnaires, including pilot studies and translation procedures. In the study IV, there is scope for discussion of the number of days needed in a food diary to best reflect actual nutrient intakes for the use of developing a diet quality index. As a compromise, a five-day food diary was chosen instead of three or seven-day food diaries, since the five-day period was not considered unreasonably burdensome for the families, but sufficiently accurate to reliably evaluate dietary intake at a group level [77,378]. Various actions were taken to ensure accurate reporting of the dietary intake, e.g. the families were given thorough instructions on how to fill in the food diary and a validated portion picture booklet [287] to help them to estimate the portion sizes. Further, the food diaries were carefully checked with the families during a study visit. Nevertheless, it is always possible that the responses are affected by some misreporting [77]. In general, self-reporting is a source of uncertainty in all of the studies included in this thesis as it may result in misreporting of data e.g. due to a recall bias or social desirability bias [379,380]. In the study II, the questionnaire was anonymous and completed electronically, thus reducing the effect of social desirability bias, and the calculation of the daily supplement intakes from the package labels may further lower the risk for possible inaccuracies encountered when inquiring about supplement use in detail. Furthermore, the observed high doses of some nutrients consumed by some of the participants might be explained if they were prescribed high doses of e.g. folic acid due to a risk for neural tube defects or iron in the case of anaemia. In the study III, the CIDQ method depends heavily on the memory of the parents, and they may not always know what their child is eating e.g. in the day care, which might increase the risk for inaccuracies. Further, the FFQ and food diary methods used in the study IV are always subject to e.g. overestimating the consumption of the recommended food choices or underestimating the consumption of the unhealthy options. However, in the study IV, the potential impact of underreporting was taken into consideration in the analyses, but it did not affect the results when selecting the final questions for the ES-CIDQ. It should also be noted that the nutrient calculation software used in the study IV uses food composition database, which is no longer being updated with the most recent food composition data by the software developer. Updating the food composition data is typically insufficient as it requires high resources. However, the database used in the present study is regularly updated by clinical nutritionists, by e.g. adding missing food items and products with their precise food composition data. Furthermore, it could be speculated whether the ES-CIDQ measures the diet quality more accurately in younger or older children in the target age group. It is possible that the dietary habits somewhat differ among 7−12-year-old children and that the children complete the index with varying accuracy depending on their age. However, dietary data of children in all elementary school grades was included in the development and validation process. Also, the reliability of the answers presumably increases when the index is completed with the help of parents, which is advisable in this age group.

Lastly, the major limitation of the study I should also be acknowledged, that is, the high dropout rate, although it is a common feature in online studies [381,382]. The dropout rate was equal between the intervention groups, indicating that the effectiveness of the intervention might not be affected by the dropout. However, the women who dropped out had lower diet quality scores in early pregnancy than the women who continued in the study; this might partially explain the relatively modest changes observed in the diet quality. The physical activity did not differ between the dropouts and participants who continued in the study and some benefits of the app use were indeed observed on maintaining physical activity during pregnancy. In addition, the dropouts were more likely to have overweight or obesity, lower educational level and lower gestational weeks as well as to be multiparous and smokers before pregnancy than the women who continued in the study, which might also influence the effects of the intervention and app use.

7 Conclusions

The main findings of this thesis are:

1. The proportion of Finnish pregnant women consuming vegetables, fruits and berries, fish, fat-free milk and vegetable oil-based spread on bread as recommended was low. Majority of the pregnant women used vitamin D and folic acid supplements, but the adherence to the recommended doses was low. Furthermore, majority of the women had low or moderate physical activity level during pregnancy and only one third of the women gained gestational weight according to recommendations.

2. No benefits of the intervention, e.g. the enhanced app use, were shown on the lifestyle habits. However, physical activity levels among app users decreased less likely compared with app non-users over the course of pregnancy, suggesting that the app may be beneficial in supporting the maintenance of physical activity as the pregnancy proceeds.

3. The quality of diet was suboptimal in most of the Finnish preschool and elementary school-aged children; this was attributable to e.g. low consumption of vegetables, fruits and berries, fat-free milk and vegetable oil-based spread on bread in both age groups. Child's weight was not associated with child's diet quality. Instead, the child's younger age was associated with better diet quality in both preschool and elementary school-aged children. Furthermore, parents' higher education and parents' self-perceived healthy diet were related to good diet quality in the preschool-aged children.

4. The developed stand-alone index depicted diet quality in elementary school-aged children as defined in the dietary recommendations. The index can be used as a valid tool in dietary screening in e.g. school health care or nutrition research.

Summary and research needs

Based on these findings, the lifestyle habits of Finnish pregnant women need improvement to support and advance the health of both the mother and the child. Although providing additional evidence-based health information in the app was not successful in supporting healthy lifestyle habits during pregnancy, health app alone may serve as an efficient tool for supporting the maintenance of physical activity during pregnancy. Further investigation with a larger number of participants might still be needed to confirm whether the health app in combination with evidence-based information on health-promoting lifestyle could be helpful. If another study would be conducted, it is important to increase the compliance by e.g. increasing the frequency of automated and/or personal contacts to the participants. Another solution could be to develop the app further with adding features related to pregnancy physiology and/or features that allow personalised approaches delivered via the app, e.g. personalised intervention messages, personalised appearance of the app or adding and hiding features based on the user’s own preference. These modifications could also increase the user-friendliness of the app, which is an important factor for the convenience of app use.

The results also showed that further actions are needed to improve the diet of Finnish preschool and elementary school-aged children. Diet quality indices can serve as valid tools for assessing the diet quality in health care practice, including school health care. The ES-CIDQ is especially beneficial for screening purposes in identifying those elementary school-aged children most in need of nutrition counselling. To further confirm the validity of the ES-CIDQ, it could be beneficial to test the use of the index against another dietary assessment method or biochemical biomarkers in another sample of elementary school-aged children. Furthermore, digitising the ES-CIDQ into an easily accessible electronic questionnaire with automated scoring system might facilitate the implementation of the ES-CIDQ in the research and clinical practice.

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Appendix

Supplementary Table 1. Examples of the intervention messages sent via the health app once a week with rotating themes.

THEME OF THE MESSAGE	EXAMPLES OF THE MESSAGES
Diet	How often do you eat fruits or berries? You can enjoy them on a daily basis also during pregnancy. Fruits and berries are a part of a diverse diet and they contain a variety of vitamins and fibres that are essential for the health of you and the baby. You can add fruits or berries e.g. to porridge, plain yoghurt, quark or curdled milk, or eat them as they are.
Physical activity	Are you physically active during pregnancy? It is recommended to exercise daily or at least 5 times a week and 30 minutes at a time. It is natural that the amount and intensity of physical activity may decrease during pregnancy, but if the pregnancy proceeds without complications, you can continue to exercise regularly towards the end of the pregnancy according to your own state of health.
Weight gain	Appropriate gestational weight gain may e.g. lower the risk of gestational diabetes and high blood pressure. Labor and delivery may also be easier if the weight gain is appropriate. Monitoring the weight gain often helps in staying on track with your weight gain goals. Thus, record your weight regularly!
Gestational diabetes	Are you diagnosed with gestational diabetes? Good management of gestational diabetes can help you prevent type 2 diabetes after pregnancy. After gestational diabetes, it is more common than usual to also develop type 2 diabetes. However, healthy eating habits, exercise and striving for a healthy weight even after the delivery may significantly reduce the risk of type 2 diabetes!

Supplementary Table 2. Food groups and the respective food items included in the groups used in the principal component analysis to identify dietary patterns in elementary school-aged children.

FOOD GROUP	**FOODS INCLUDED IN THE FOOD GROUP**
Whole grain products	• Whole grain bread • Whole grain cereal • Other whole grain products, such as bran, groats and whole grain macaroni
Sweet grain products	• Cookies, chocolate and toffee wafers etc. • Snack bars and snack biscuits
Other grain products	• White bread and other white grain products, such as wheat flour, macaroni, rice, muesli bars, rice cakes etc. • Other cereal such as oat and rice cereal • Other grain products such as oat and muesli snacks
Vegetables, root vegetables and mushrooms	• Vegetables such as cucumber, tomato, cabbage, lettuce, greens, preserved vegetables and frozen vegetables • Root vegetables such as carrot, beetroot, soup root vegetables, baby food with root vegetables • Mushrooms
Pulses, nuts and other vegetable products	• Pulses, such as peas, bean, soybean, sprouts etc. • Nuts, almonds, seeds • Vegetable products like tofu, vegetable pastes, soy pudding, seaweed
Potato	• Potato, instant mashed potatoes etc.
Fruits, berries and 100% fruit juices	• Fruits • Berries • 100% fruit juices
Butter and other dietary fats	• Butter and butter−vegetable oil mix, such as Oivariini • Other dietary fats, such as pastry margarine, lard, coconut butter
Margarine and oils	• Vegetable oil-based spreads and margarines with fat content of <60% and 60-80% • Liquid margarine • Oils and oil-based salad dressings
Meat and meat products	• Pork and beef • Sausages like frankfurter, bologna ring, bologna "saturday" sausage, mettwurst • Offal • Game and other meat such as sheep, horse and reindeer
Poultry	• Broiler, turkey etc.

FOOD GROUP	FOODS INCLUDED IN THE FOOD GROUP
Fish and fish products	• Fish • Shellfish • Fish products such as salted and smoked fish, canned fish, roe paste
Egg dishes	• Egg, omelette
Low-fat dairy products	• Low-fat (<1% fat) milk and milk drinks • Low-fat (<1% fat) dairy products such as sour milk, viili, quark, yoghurts
High-fat dairy products	• High-fat (≥1% fat) milks and milk drinks • High-fat (≥1% fat) dairy products such as sour milk, viili, quark, yoghurt • Creams and other dairy-like products such as plant drinks, plant yoghurts, sour cream, smetana, whey protein
Cheese and cheese-like products	• High-fat cheese (>17% fat), such as processed cheese, feta, mold-ripened cheese • Low-fat cheese (≤17% fat), such as processed cheese, feta, cottage cheese • Cheese-like products, such as cheese and cream cheese made from plant-based fat
Sugar-sweetened beverages	• Sugar-sweetened beverages, such as juice and soft drinks
Sugar-free beverages	• Sugar-free beverages, such as like juice and soft drinks
Sugar, sweets, ice cream and jam	• Sugar, syrup, honey etc. • Sweets • Chocolate and cocoa powder • Ice cream • Jam
Convenience food	• Convenience food, such as instant soups, meat pasties, instant pot casseroles, hamburgers, pizza, nuggets and ready-made salads, such as beetroot salad with mayonnaise base • Karelian pies • Spices and sauces
Salty snacks	• Popcorn • Potato chips, cheese puffs etc. • Nachos and tacos • Salted crackers and salt sticks

Supplementary Table 3. Daily intakes of energy, energy-yielding nutrients, vitamins and minerals in all children and in children with normal weight or overweight/obesity as assessed by the five-day food diary.

NUTRIENT [a,b]	ALL CHILDREN (n=218)*	CHILDREN WITH NORMAL WEIGHT (n=181)	CHILDREN WITH OVERWEIGHT/OBESITY (n=37)	P-VALUE
Energy, MJ	6.6 ± 1.3	6.6 ± 1.2	6.8 ± 1.4	0.37[c]
Carbohydrates, E%	49.0 (46.0–52.4)	48.8 (46.1–52.5)	49.5 (44.9–52.2)	0.97[d]
Carbohydrates, g	191.2 ± 40.5	190.3 ± 39.7	195.2 ± 44.2	0.51[c]
Sucrose, E%	10.6 ± 3.8	10.6 ± 3.9	10.6 ± 3.7	0.99[c]
Sucrose, g	39.3 (29.6–52.6)	39.2 (29.6–52.7)	40.6 (29.4–54.3)	0.69[d]
Fiber, g/MJ	2.5 ± 0.7	2.6 ± 0.7	2.4 ± 0.7	0.13[c]
Fiber, g	15.6 (12.4–20.0)	15.6 (12.7–20.0)	15.6 (11.6–19.7)	0.54[d]
Protein, E%	16.2 (14.7–18.1)	16.2 (14.7–18.0)	15.2 (14.3–18.6)	0.83[d]
Protein, g	62.9 (53.2–73.0)	62.7 (53.2–72.9)	65.1 (53.2–74.2)	0.51[d]
Total fat, E%	33.4 (30.1–36.7)	33.8 (30.2–36.9)	32.9 (29.8–36.5)	0.74[d]
Total fat, g	56.5 (48.8–69.1)	55.8 (48.5–68.7)	59.9 (48.1–71.8)	0.47[d]
Saturated fatty acids (SFA), E%	13.5 (11.6–15.1)	13.5 (11.5–15.1)	13.3 (11.9–15.1)	0.70[d]
Saturated fatty acids (SFA), g	22.7 (19.0–27.6)	22.3 (18.9–27.2)	24.4 (19.1–28.6)	0.31[d]
Monounsaturated fatty acids (MUFA), E%	11.1 (10.0–12.5)	11.1 (10.0–12.2)	11.2 (9.8–12.6)	0.96[d]
Monounsaturated fatty acids (MUFA), g	18.9 (15.9–23.2)	18.6 (15.9–22.8)	20.1 (15.8–24.4)	0.48[d]
Polyunsaturated fatty acids (PUFA), E%	5.3 (4.5–6.3)	5.3 (4.5–6.3)	5.5 (4.6–6.2)	0.96[d]
Polyunsaturated fatty acids (PUFA), g	9.0 (7.2–11.3)	9.0 (7.3–11.2)	9.4 (6.7–12.5)	0.76[d]
PUFA:SFA ratio	0.40 (0.33–0.50)	0.40 (0.33–0.51)	0.41 (0.33–0.49)	0.90[d]
Cholesterol, mg	185.5 ± 76.4	183.8 ± 77.3	193.7 ± 72.4	0.47[c]
Retinol equivalent, RE	738.4 (499.8–1019.9)	738.5 (502.0–984.5)	722.5 (486.6–1213.2)	0.96[d]
Vitamin d, mg	8.4 (6.1–11.8)	8.6 (6.2–11.8)	7.9 (6.0–12.0)	0.59[d]
Vitamin e, mg	6.7 (5.5–8.4)	6.8 (5.6–8.4)	6.6 (5.0–8.9)	0.41[d]
Thiamin, mg	1.0 ± 0.3	1.0 ± 0.3	1.1 ± 0.3	0.046[c]
Riboflavin, mg	1.7 (1.4–2.2)	1.7 (1.4–2.2)	1.7 (1.4–2.2)	0.74[d]
Niacin equivalent, NE	23.3 ± 6.1	23.9 ± 6.0	25.1 ± 6.5	0.28[c]

NUTRIENT [a,b]	ALL CHILDREN (n=218)*	CHILDREN WITH NORMAL WEIGHT (n=181)	CHILDREN WITH OVERWEIGHT/OBESITY (n=37)	P-VALUE
Vitamin B6, mg	1.6 (1.4–1.9)	1.7 (1.4–2.2)	1.7 (1.4–2.2)	0.83[d]
Vitamin B12, µg	4.4 (3.4–5.8)	4.4 (3.4–5.7)	4.4 (3.5–6.2)	0.50[d]
Folic acid, µg	181.6 (150.9–219.5)	180.1 (148.4–216.2)	183.5 (151.7–239.4)	0.51[d]
Pantothenic acid, mg	4.5 ± 1.3	4.5 ± 1.3	4.5 ± 1.3	1.00[c]
Biotin, µg	27.2 ± 8.6	27.3 ± 8.5	26.8 ± 9.1	0.77[c]
Vitamin C, mg	80.4 (57.1–113.1)	80.1 (57.1–112.4)	94.6 (56.6–115.0)	0.56[d]
Sodium, mg	2215.1 (1845.0–2589.6)	2202.3 (1796.8–2552.8)	2243.4 (1891.6–2870.0)	0.12[d]
Potassium, mg	2669.5 (2304.3–3248.1)	2643.1 (2286.9–3236.9)	2892.7 (2307.4–3277.5)	0.36[d]
Calcium, mg	978.0 (753.0–1292.6)	1000.9 (763.3–1298.9)	975.4 (696.2–1303.6)	0.77[d]
Magnesium, mg	257.2 (218.4–306.9)	258.3 (219.3–309.4)	248.9 (205.5–305.7)	0.78[d]
Phosphorus, mg	1240.3 (1022.0–1474.2)	1243.0 (1017.2–1475.3)	1188.6 (1036.0–1511.8)	0.92[d]
Iron, mg	8.2 ± 2.1	8.2 ± 2.0	8.5 ± 2.4	0.37[c]
Manganese, mg	2.6 (2.0–3.6)	2.8 (2.0–3.7)	2.4 (1.9–3.1)	0.14[d]
Zinc, mg	9.2 (7.9–10.9)	9.3 (8.1–10.9)	9.0 (7.6–11.1)	0.88[d]
Iodine, µg	174.5 ± 54.6	172.8 ± 52.6	182.7 ± 63.6	0.31[c]
Selenium, µg	57.3 ± 15.4	56.6 ± 14.3	60.8 ± 19.9	0.14[c]

Data presented as median (lower−upper quartile) or mean ± standard deviation. E%, proportion of energy intake; MJ, megajoule. *Children with underweight excluded from the analyses. [a] Recommended intake of energy-yielding nutrients: protein 10−20 E%, carbohydrates 45−60 E%, sucrose <10 E%, total fat 25−40 E%, saturated fatty acids <10E%, monounsaturated fatty acids 10−20 E% and polyunsaturated fatty acids 5−10 E%. [b] Recommended intake of vitamins and minerals: vitamin A (retinol equivalent) 400 RE (6−9-year-olds) and 600 RE (10−13-year-olds), vitamin D 10 µg, vitamin E 6 mg (6−9-year-olds) and 7/8 mg (10−13 years old girls/boys), thiamin 0.9 mg (6−9-year-olds) and 1.0/1.1 mg (10−13 years old girls/boys), riboflavin 1.1 mg (6−9-year-olds) and 1.2/1.3 mg (10−13 years old girls/boys), niacin (niacin equivalent) 12 NE (6−9-year-olds) and 14/15 NE (10−13 years old girls/boys), vitamin B6 1.0 mg (6−9-year-olds) and 1.1/1.2 mg (10−13 years old girls/boys), vitamin B12 1.3 µg (6−9-year-olds) and 2.0 µg (10−13-year-olds), folate 130 µg (6−9-year-olds) and 200 µg (10−13-year-olds), vitamin C 40 mg (6−9-year-olds) and 50 mg (10−13-year-olds), calcium 700 mg (6−9-year-olds) and 900 mg (10−13-year-olds), phosphorus 540 mg (6−9-year-olds) and 700 mg (10−13-year-olds), potassium 2.0 g (6−9-year-olds) and 2.9/3.3 g (10−13 years old girls/boys), magnesium 200 mg (6−9-year-olds) and 280 mg (10−13-year-olds), iron 9 mg (6−9-year-olds) and 11 mg (10−13-year-olds), zinc 7 mg (6−9-year-olds) and 8/11 mg (10−13-years-old girls/boys), copper 0.5 mg (6−9-year-olds) and 0.7 mg (10−13-year-olds), iodine 120 µg (6−9-year-olds) and 150 µg (10−13-year-olds), selenium 30 µg (6−9-year-olds) and 40 µg (10−13-year-olds). [c] Independent-samples T-test. [d] Mann-Whitney U-test.

Supplementary Table 4. Food consumption compared to the dietary recommendations, the consumption of snacks and fast food, eating frequency and food consumption (g/d) in all children and in children with normal weight or overweight/obesity.

EATING HABITS	TOTAL N	ALL CHILDREN (n=218)*	CHILDREN WITH NORMAL WEIGHT (n=181)	CHILDREN WITH OVERWEIGHT/OBESITY (n=37)	P-VALUE
FOOD CONSUMPTION IN ACCORDANCE WITH DIETARY RECOMMENDATIONS [a]					
Vegetables, fruits and berries ≥5 portions per day	216/179/37	26 (12.0)	19 (10.6)	7 (18.9)	0.17[b]
Fish ≥2 portions per week	215/178/37	78 (36.3)	63 (35.4)	15 (40.5)	0.58[b]
Vegetable oil-based spreads (60-80 % fat) on bread	215/178/37	79 (36.7)	68 (38.2)	11 (29.7)	0.36[b]
Skimmed milk	215/178/37	117 (54.4)	97 (54.5)	20 (54.1)	1.00[b]
CONSUMPTION OF SNACKS AND FAST FOOD [a]					
Sweets, days per week	215/178/37				0.30[b]
0		36 (16.7)	27 (15.2)	9 (24.3)	
1		103 (47.9)	85 (47.8)	18 (48.6)	
≥2		76 (35.3)	66 (37.1)	10 (27.0)	
Chocolate, days per week	216/179/37				0.14[b]
0		102 (47.2)	85 (47.5)	17 (45.9)	
1		69 (31.9)	53 (29.6)	16 (43.2)	
≥2		45 (20.8)	41 (22.9)	4 (10.8)	
Potato chips and cheese puffs, days per week	216/179/37				0.70[b]
0		115 (53.2)	93 (52.0)	22 (59.5)	
1		79 (36.6)	67 (37.4)	12 (32.4)	
≥2		22 (10.2)	19 (10.6)	3 (8.1)	
Popcorn, days per week	216/179/37				0.51[b]
0		171 (79.2)	140 (78.2)	31 (83.8)	
≥1		45 (20.8)	39 (21.8)	6 (16.2)	

EATING HABITS	TOTAL N	ALL CHILDREN (n=218)*	CHILDREN WITH NORMAL WEIGHT (n=181)	CHILDREN WITH OVERWEIGHT/OBESITY (n=37)	P-VALUE
Ice cream, days per week	216/179/37				0.064[b]
0		75 (34.7)	68 (38.0)	7 (18.9)	
1		69 (31.9)	56 (31.3)	13 (35.1)	
≥2		72 (33.3)	55 (30.7)	17 (45.9)	
Pastries, days per week	215/178/37				0.86[b]
0		72 (33.5)	61 (34.3)	11 (29.7)	
1		84 (39.1)	69 (38.8)	15 (40.5)	
≥2		59 (27.4)	48 (27.0)	11 (29.7)	
Cookies, days per week	215/178/37				0.46[b]
0		95 (44.2)	78 (43.8)	17 (45.9)	
1		69 (32.1)	55 (30.9)	14 (37.8)	
≥2		51 (23.7)	45 (25.3)	6 (16.2)	
Snack bars, days per week	216/179/37				0.75[b]
0		149 (69.0)	122 (68.2)	27 (73.0)	
1		35 (16.2)	29 (16.2)	6 (16.2)	
≥2		32 (14.8)	28 (15.6)	4 (10.8)	
Sugar-sweetened juice, days per week	215/178/37				0.42[b]
0		82 (38.1)	69 (38.8)	13 (35.1)	
1		44 (20.5)	36 (20.2)	8 (21.6)	
2		44 (20.5)	39 (21.9)	5 (13.5)	
≥3		45 (20.9)	34 (19.1)	11 (29.7)	
Sugar-sweetened soft drinks, days per week	214/178/36				0.74[b]
0		95 (44.4)	77 (43.3)	18 (50.0)	
1		69 (32.2)	59 (33.1)	10 (27.8)	
≥2		50 (23.4)	42 (23.6)	8 (22.2)	

EATING HABITS	**TOTAL N**	**ALL CHILDREN (n=218)***	**CHILDREN WITH NORMAL WEIGHT (n=181)**	**CHILDREN WITH OVERWEIGHT/OBESITY (n=37)**	**P-VALUE**
Sugar-free juice, days per week	213/177/36				0.28[b]
0		185 (86.9)	156 (88.1)	29 (80.6)	
≥1		28 (13.1)	21 (11.9)	7 (19.4)	
Sugar-free soft drinks, days per week	214/178/36				0.18[b]
0		187 (87.4)	158 (88.8)	29 (80.6)	
≥1		27 (12.6)	20 (11.2)	7 (19.4)	
Pizza, days per week	215/178/37				0.088[b]
0		139 (64.7)	120 (67.4)	19 (51.4)	
≥1		76 (35.3)	58 (32.6)	18 (48.6)	
Hamburger, days per week	215/179/36				0.55[b]
0		152 (70.7)	128 (71.5)	24 (66.7)	
≥1		63 (29.3)	51 (28.5)	12 (33.3)	
EATING FREQUENCY [a]					
Regular eating frequency (3-4 h)					
On weekdays	205/171/34	170 (82.9)	144 (84.2)	26 (76.5)	0.32[b]
On weekends	215/178/37	159 (74.0)	131 (73.6)	28 (75.7)	1.00[b]
Eating habits differ between weekdays and weekend days	216/179/37	157 (72.7)	135 (75.4)	22 (59.5)	0.067[b]
Skipping meals (breakfast, lunch and/or dinner) on weekend days	216/179/37	29 (13.4)	27 (15.1)	2 (5.4)	0.18[b]
FOOD CONSUMPTION, g/d [c]					
Grain products	218/181/37	176.6 (147.3 – 215.7)	177.1 (147.3 – 214.7)	172.3 (143.0 – 218.1)	0.97[d]
Root vegetables and nuts	218/181/37	108.0 (70.9 – 142.7)	104.4 (68.7 – 142.6)	112.7 (93.6 – 144.1)	0.16[d]
Vegetables	218/181/37	85.0 ± 51.8	86.0 ± 52.5	80.3 ± 48.4	0.55[e]
Fruits and berries	218/181/37	126.0 (66.3 – 211.8)	132.9 (66.6 – 213.3)	106.0 (50.0 – 208.9)	0.52[d]

EATING HABITS	TOTAL N	ALL CHILDREN (n=218)*	CHILDREN WITH NORMAL WEIGHT (n=181)	CHILDREN WITH OVERWEIGHT/OBESITY (n=37)	P-VALUE
Fat products	218/181/37	25.6 (18.9 – 34.9)	26.2 (19.6 – 35.0)	21.4 (16.6 – 35.3)	0.23[d]
Dairy and dairy-like products	218/181/37	575.8 (407.0 – 771.8)	584.4 (414.4 – 768.2)	533.0 (398.9 – 806.9)	0.87[d]
Meat and meat products	218/181/37	78.1 (53.8 – 107.6)	76.1 (52.4 – 103.0)	83.1 (61.7 – 118.1)	0.16[d]
Fish and fish products	218/181/37	13.0 (5.6 – 25.8)	12.3 (5.0 – 24.8)	13.9 (7.0 – 34.1)	0.21[d]
Egg dishes	218/181/37	11.1 (5.3 – 21.5)	10.9 (5.2 – 21.2)	11.4 (7.3 – 22.1)	0.35[d]
Beverages	218/181/37	243.9 (167.5 – 347.0)	246.2 (162.7 – 347.1)	240.6 (190.7 – 376.8)	0.36[d]
Sugar and sweets	218/181/37	23.3 (11.6 – 40.8)	24.3 (11.8 – 41.3)	19.2 (10.2 – 41.0)	0.65[d]
Other products like processed foods	218/181/37	20.4 (8.0 – 39.0)	17.0 (7.6 – 35.2)	34.5 (11.3 – 59.6)	0.005[d]

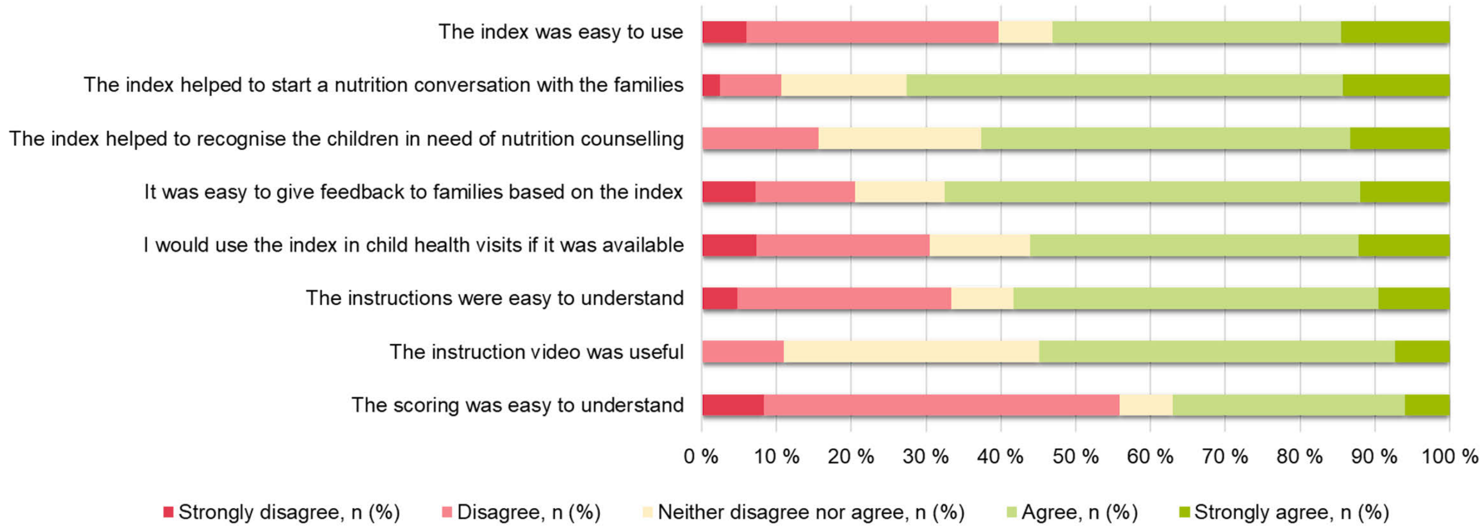
Data presented as n (%), median (lower−upper quartile) or mean ± standard deviation. *Children with underweight excluded from the analyses. [a] Assessed by the food frequency questionnaire. [b] Chi-square test. [c] Assessed by the five-day food diary. [d] Mann-Whitney U test. [e] Independent-samples t-test.

Supplementary Table 5. The proportion of all participants and app non-users, occasional users and frequent users agreeing (strongly agree or agree) with the statements regarding the use of the health app.

STATEMENT	TOTAL N	ALL WOMEN (n=1038)[a]		NON-USER (n=652)[a]		OCCASIONAL USER (n=193)[a]		FREQUENT USER (n=193)[a]		P-VALUE[b]
		N agreeing with the statement[c]	%	N agreeing with the statement[c]	%	N agreeing with the statement[c]	%	N agreeing with the statement[c]	%	
It is nice to use the app	308/113/62/133	83	26.9	14	12.4	4	6.5	65	48.9	<0.001
It is difficult to use the app	325/125/64/136	176	54.2	85	68.0	47	73.4	44	32.4	<0.001
I have had technical problems with the app	296/102/52/142	85	28.7	24	23.5	17	32.7	44	31.0	0.35
It suits me well to record lifestyle factors in the app daily	319/119/63/137	56	17.6	13	10.9	3	4.8	40	29.2	<0.001
It suits me well to record lifestyle factors in the app weekly	314/120/59/135	113	36.0	37	30.8	13	22.0	63	46.7	0.001
By using the app, I have tried to increase my vegetable consumption	253/81/42/130	76	30.0	13	16.0	7	16.7	56	43.1	<0.001
By using the app, I have tried to increase my fruit consumption	257/81/42/134	74	28.8	15	18.5	6	14.3	53	39.6	<0.001
By using the app, I have tried to improve my eating habits as a whole	254/82/42/130	73	28.7	15	18.3	7	16.7	51	39.2	<0.001
By using the app, I have tried to increase my physical activity	259/83/40/136	57	22.0	12	14.5	3	7.5	42	30.9	<0.001

STATEMENT	TOTAL N	ALL WOMEN (n=1038)[a]		NON-USER (n=652)[a]		OCCASIONAL USER (n=193)[a]		FREQUENT USER (n=193)[a]		P-VALUE[b]
By using the app, I have tried to improve my lifestyle overall	246/80/40/126	58	23.6	13	16.3	5	12.5	40	31.7	0.008
Using the app has not affected my lifestyle	262/88/45/129	170	64.9	64	72.7	34	75.6	72	55.8	0.010
It has been easy to follow my weight during pregnancy with the app	232/73/41/118	52	22.4	13	17.8	3	7.3	36	30.5	0.005
It has been easy to follow my blood glucose values during pregnancy with the app	78/31/15/32	15	19.2	5	16.1	0	0.0	10	31.3	0.034
I will probably use the app during the whole pregnancy	326/128/63/135	70	21.5	9	7.0	0	0.0	61	45.2	<0.001
I would probably use the app if I became pregnant again	292/115/59/118	49	16.8	18	15.7	3	5.1	28	23.7	0.007
I could recommend the use of the app to my friend when she's pregnant	299/113/59/127	87	29.1	27	23.9	6	10.2	54	42.5	<0.001

[a] The full number of participants (in the group). [b] chi-squared test. [c] Combination of answers 'strongly agree' and 'agree' compared with combination of answers 'strongly disagree' and 'disagree'; women answering 'not sure' were excluded from the analyses.



Supplementary Figure 1. Views of the child health clinic nurses (n=85) on the feasibility of adopting the Children's Index of Diet Quality (CIDQ) as part of their health counselling practices. The nurses' views were inquired with a questionnaire within the study III, in which also the preschool-aged child's diet quality and anthropometric data as well as parental views on child feeding and health were investigated.

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