Mobile Nutrition Monitoring for Well-being

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ABSTRACT

The EU-funded project WellCo[1] aims to deliver a new mobile app with a virtual coach to encourage the users towards healthier behaviour choices in order to improve their physical, cognitive, mental and social well-being. Healthy nutrition can substantially contribute to health and wellbeing. We will use different techniques for dietary assessment in the WellCo project - eating detection by gesture recognition using a wrist-worn device, and estimating the quality of diet by self-reporting using a Food Frequency Questionnaire (FFQ). This paper describes the latter. We designed a short FFQ, compared it to validated questionnaires, and developed a web service and a web application to determine dietary quality score for each user by using the designed FFQ.

KEYWORDS

short food frequency questionnaire, nutrition monitoring, dietary assessment, web service

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1 INTRODUCTION

The WellCo project[1] aims to provide a mobile app featuring a virtual coach for behaviour changes aiming to achieve for healthier lifestyle. The app has different modules for monitoring quality of life - nutrition, physical activity, physical health, mental health, social well-being etc.

This paper describes the module to monitor nutrition and nutrition-related activities, as proper diet is beneficial for healthy lifestyle and helps to prevent many chronic diseases, such as cancer, diabetes, hypertension. There are many approaches for nutrition monitoring. Most commonly used methods are based on self-reporting - either by 24-hour dietary recalls or Food Frequency Questionnaires (FFQs). Due to possible inaccuracy, automated dietary monitoring solutions have become of greater importance. Advances in body-worn sensors have led to systems with high accuracy of recognizing time, quantity and even type of food consumed in each bite. By using wristbands (or smartwatches) to collect data, it is possible to recognize eating gestures [7] er even count 'bites' or assess caloric intake [9]. Although automated monitoring has become really important in nutrition monitoring it only gives quantitative information (when is the user eating, how much did he eat...), while qualitative information (what is the user eating) is still most reliable by using dietary reaclls or FFQs.

In the WellCo project we decided to monitor nutrition by combining two approaches. By self-reports we will try to assess the qualitative aspect of nutrition (which food does the user typically consume) and by using data from a wrist-worn device we expect to assess the quantitative aspect (number ob bites, amount of eaten food etc.) This paper will discuss the first approach. We evaluated both dietary recalls and FFQs as self-reporting methods. However, dietary recalls require typing or complex food item selection which can be cumbersome on mobile devices, so we opted for FFQ. The developed FFQ covers all key aspects of healthy diet, and is modular, so that only questions pertaining to certain aspects can be asked. This is important in ubiquitous settings where one wishes to minimize the required inputs from the user.

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The paper describes the FFQ, its web-service implementation and experimental evaluation.

2 FFQ DESIGN AND IMPLEMENTATION

Questionnaire

When designing the FFQ, we started with aspects of nutrition we wanted to address, since the coach will recommend these as goals to the user. We chose: *Fruit, Vegetables, (Oily) Fish, Fat, Sugar, Protein, Fibre* and *Salt*. Furthermore, we required the questionnaire to be short and validated. This means we want to have as few questions as possible formatted in such a way that each of them covers as many *goals* (fruit, vegetables, fish, amount of salt...) as possible. There are validated short questionnaires available, but we could not find any which would cover all our requirements.

Short-Form FFQ as the starting point. Cleghorn et al. [2] have developed a short-form FFQ (SFFFQ), which was validated by comparing its outcome to outcome from more comprehensive FFQ and by 24h Food Recall Diary. The SFFFQ consists of twenty questions and it covers five of the above mentioned nutrition groups / goals. The questions are listed in Table 1. It returns quality scores for *fruit*, *vegetables*, *oily fish*, *fat* and *NMES - non-milk extrinsic sugar* consumption alongside the average dietary score. Standard portion sizes were assigned to each food item. This portions were then multiplied by the daily frequency, giving an estimate of grams for each food item consumed per person per day. Then, the UK dietary recommendations were taken into account and scores from 1-3 were allocated for each food/nutrient group (the higher the score, the better the diet).

As SFFFQ has been shown to cover five of our goals well, we decided to take this questionnaire as our basis, adjusting the dietary recommendations to the Slovenian dietary recommendations ([4], [6]) for each group (Table 3). Adjustment of the SFFFQ to different national dietary recommendation is quite straightforward and the SFFFQ is easy to modify for different countries.

Extension of SFFFQ. To cover the other goals (*fibre*, *salt*, *protein*, *water*), we had to add additional questions (food items), assign portion size and nutrition values for the existing five nutrition groups (*fruit, vegetables*, *fish*, *fat*, *sugar (NMES)* for all of them and allocate the scores from 1 to 3 based on national dietary recommendations. The list of the additional questions (food items) is provided in Table 2 and the assigned scores are in Table 3.

Implementation as a Web service

We developed a web service for delivery and management of our ESFFFQ. The web service will be integrated in the WellCo system, but is designed generally so it can also be

How often do you eat/drink...
Fruit (tinned/fresh)?
Juice (not cordial or squash)?
Salad (not garnish or addded to sandwiches)?
Vegetables (tinned/frozen/fresh, but not potatoes)?
Chips / Fried potatoes?
Beans or pulses (baked beans, chick peas, dahl...)?
Fibre-rich breakfast cereal (porridge, muesli...)?
Cheese / Yogurt?
Crisps / Savoury snacks?
Sweet biscuits, cakes, chocolate, sweets?
Ice cream / Cream?
Non-alcoholic fizzy drinks / pop not sugar free or diet?
Beef, lamb, pork, ham (steaks, roasts, joints, chops...)?
Chicken, turkey (steaks, roasts... - not in batter/breadcrumbs)?
Sausages, bacon, corned beef, meat pies / pasties...?
Chicken, turkey (nuggets/twizzlers, pies or in batter/breadcrumbs)?
While fish in batter or breadcrumbs?
White fish **NOT** in batter or breadcrumbs?

Table 1: List of questions in the original SFFFQ

How often do you eat/drink...
Nuts, peanuts or seeds?
Grains (pasta, rice, couscous, bulgur...)?
Pre-prepared sauces, gravies, dry soup mixes?
Pizza, pasta/noodle dishes with cheese sauce?
Bread, buns and other bread pastries (non-sweet)?
Potato (mashed, baked, cooked; not fried)?
Eggs (boiled, fried, scrambled,...)?

Table 2: List of additional questions in ESFFFQ

Score	1	2	3
Fruit	$\leq$ 2 serv/week	$>$ 2 serv/week and $\leq$ 2 serv/day	$>$ 2 serv/day
Vegetables	$\leq$ 2 serv/day	$1-3$ serv/day	$>$ 3 serv/day
(Oily) Fish	No intake	1 serv/week	2 serv/week
Fat	$\geq$ 111 g/day	$<$ 111 g/day and $\geq$ 74 g/day	$<$ 74 g/day
Sugar	$\geq$ 82.5 g/day	$<$ 82.5 g/day and $\geq$ 55 g/day	$<$ 55 g/day
Protein	0.8·BM	from 0.8·BM to 1.0·BM g/day	1.0·BM g/day
Fibre	$\leq$ 25 g/day	$>$ 25 g/day and $\leq$ 30g/day	$>$ 30 g/day
Salt	$>$ 6g/day	/	$\leq$ 6 g/day

Table 3: Dietary score according to the Slovenian national dietary recommendations given in servings per day (serv/day), servings per week (serv/week) or amount (g/day). Boundaries for proteins are calcualted as 0.8·BM (body mass) g/day to 1.0·BM g/day

integrated in other applications. While it was developed with our questionnaire in mind, it is also general in the sense that it can support different FFQs. The web service consists of two parts. The first part is meant for questionnaire formation and is used to assign nutrition goals to questions, store the relations between nutrition values, individual questions and goals, and store the scoring information by taking into account different national dietary recommendations. A web application was developed to help an administrator manage this part – a screenshot from this application is shown in 1.

The second part of the web service is meant for the end-users, and it delivers them the questionnaire based on their chosen nutrition goals, as well as calculates the nutrition scores based on the appropriate national dietary recommendations. It can suggest goals based on the users' previous answers, and it allows the users to choose goals based on their personal preference. Stored user scores are then used for further monitoring – for goal suggestion and for assigning the order of importance to each question.

3 EXPERIMENTAL EVALUATION

36 people (20 male and 16 female) from 22 to 65 years old were involved in our research. All of them were asked to answer the developed ESFFFQ and three validated questionnaires (about protein, fibre and salt) we used to validate the questions we added to the original SFFFQ. All of the participants answered the ESFFFQ, 30 people answered the questionnaire about protein consumption, 27 of them answered the questionnaire about fibre consumption and 25 of them answered the questionnaire about salt consumption.

Results. To check the validity of the added questions in our ESFFFQ, the scores for the additional goals (protein, salt and fibre) were compared with the three validated goal-specific questionnaires.

- *Salt.* To check the score validity for the consumption of salt, we have used the questionnaire developed by Meson et al. [5]. This questionnaire only tells if somebody is high-sodium or low-sodium consumer. In our scoring system this corresponds to eating more (score 1) or less (score 3) than 6 g of salt per day. From the 25 people who answered both of them, 17 of them got the same feedback from both questionnaires - they are either low- or high-sodium consumers, which means the match 68%. Another 4 were very close to boundary values in both questionnaires and would easily be put in another group just by changing one answer.

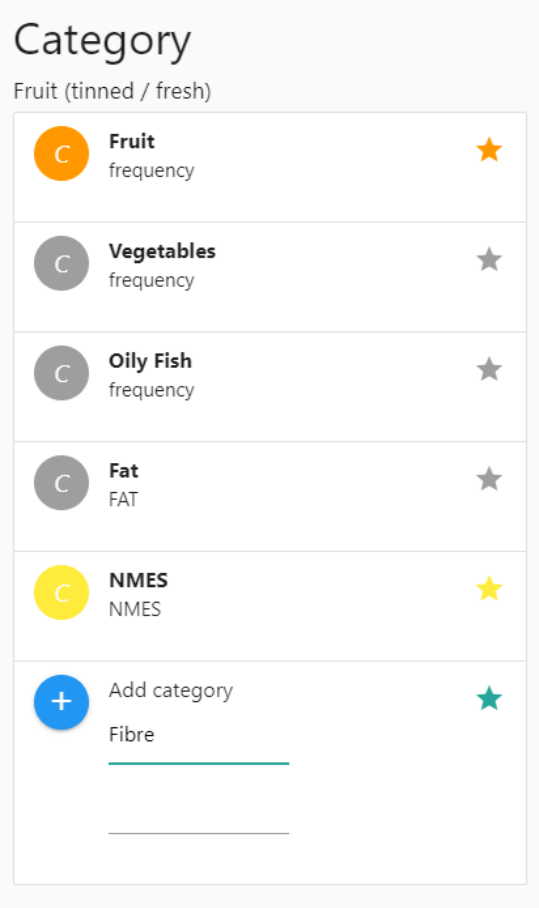

Figure 1: The figure shows how to add a category (goal) to a specific question. For instance - a question that asks about frequency of fruit consumption affects the score on fruit consumption and the score on sugar consumption. It also affects the score on fibre consumption, so this category could be added easily.

- *Protein.* We have used an online screener, The Protein Screener 55+(Pro^{55+})[2], developed by Wijnhoven et al. [8]. This tool returns information on the probability that somebody is not consuming enough proteins. Our scoring system returns three scores, but we transformed score 1 to "not-enough-proteins" and scores 2 and 3 to "enough-proteins" so we could compare the results with those from Pro55+. From 30 people who answered both questionnaires, 17 got the same result from both questionnaires - either they eat enough proteins or not. 5 of them were again quite close to the boudaries. However, in most cases, where results do not agree, people got better scores using ESFFFQ. This might be explained with the fact that we put a lot of

[2]http://proteinscreener.nl/#/

Fruit and Vegetables	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ a Day
Fruit (tinned / fresh)	0	0	4	11.2	28.8	56.8	120	280
Fruit juice (not cordial or squash)	0	0	7.25	20.3	52.2	102.95	217.5	507.5

Figure 2: The figure shows how to add values (amount in g/day) to each possible answer of a specific question.

impact on proteins one consumes by eating meat, fish and legumes, while Pro55+ puts focus mainly on proteins consumed with diary products.

- *Fibre* The online tool NutritionQuest[3] has been used to determine the approximate amount of fibres eaten. This specific tool has not been validated. However, Healy et al.[3] designed and validated a short FFQ which consists of five food groups containing the most fibre (vegetables, fruits, breads and cereals, nuts and seeds and legumes) which account for 73.5% of the dietary fibre in New Zealand diet [1]. The NutritionQuest tool uses all of the questions from the mentioned validated questionnaire and returns the approximate amount of fibre eaten per day. We assigned the scores as in Table 3. From 27 people who answered both questionnaires, 22 people got same score from NutritionQuest and our ESFFFQ, which is 81.5%.

4 CONCLUSION AND FUTURE WORK

FFQs are a well established tool, but their predominant use is in epidemiological and research similar, not as a part of ubiquitous systems. It is telling that SFFFQ was the only FFQ suitable for such applications we found – others were either too long or lacked scientific basis. While technologically more advanced methods such as food recognition with computer vision are being developed, they are not yet sufficiently mature for general use. We therefore believe that the proposed ESSFFQ is a valuable tool for qualitative mobile assessment of nutrition.

The developed FFQ (ESFFFQ) can be used to support a wide range of nutrition goals and minimizes the number of questions asked, so it is suitable for mobile nutrition monitoring. We implemented it as a web service. We validated the developed questionnaire (the added questions) with three validated goal-specific questionnaires for salt, proteins and fibres. All of the questions probably will not asked at the same time (this could be too wearying for some users), so we would also like to come up with a smart solution for ranking questions with respect to their contribution to scores for chosen goals. Besides being used in the WellCo project, the developed system (questionnaire and web service) might be a useful tool for nutrition experts and an interesting application for individuals interested in monitoring their nutrition. In the future, we will focus on qualitative nutrition monitoring with a smartwatch. We will study how to combine this with the qualitative information obtained from the ESFFFQ, and whether we can increase the accuracy of nutrition monitoring this way.

[3]http://nutritionquest.com/wellness/free-assessment-tools-for-individuals/fruit-vegetable-fiber-screener/

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