Review of Mobile Health (mHealth) Solutions for Food-related Conditions and Nutritional Risk Factors

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***Abstract*—Representing a subarea of eHealth and Telemedicine, mHealth solutions are becoming more and more widespread. Food-related conditions, like food hypersensitivities, diabetes, obesity and associated risk factors, pose a major threat to the public worldwide. This paper investigates the variety of mHealth solutions in the area of food-related health conditions and assesses their potentials for the affected end-users, related health professionals and possible health economic impacts. A wealth of mHealth approaches targeted at the area of food and health exist; however, several areas for improvement are revealed.**

***Keywords*-Personalized eHealth; mHealth; food-related diseases; diet; nutritional risk factors**

I. INTRODUCTION

With the increased availability of smartphones, tablet PCs and other mobile computing devices, the Mobile Health (mHealth) approach is gaining increasing relevance in the field of Telemedicine. Especially food-related chronic conditions – such as food hypersensitivities, obesity, diabetes, etc. – are of special interest as the number of affected people has been rising in the last decades, and diseases with major nutritional determinants make up 41% of disability-adjusted life years among all diagnosed diseases in Europe [1]. Here, mHealth approaches seem to be promising in the context of primary and secondary prevention through dietary recommendations and food intake monitoring.

This paper provides a state of the art overview of existing mHealth solutions targeted to food-related chronic conditions and assesses their benefits to the end users and health care professionals, if feasible. After a first overview of food-related diseases and their impact, we present solutions available for specific conditions and more general mHealth concepts available for food intake monitoring, food information and diet management. Their current potential and shortcomings are discussed and finally, conclusions are drawn.

II. FOOD-RELATED CONDITIONS AND RISK FACTORS

This section gives an overview of food-related diseases and associated major risk factors. In order to give an indicator for the relevance of each condition, we present prevalence figures where feasible. Most of the presented illnesses show a potential for using mHealth for primary or secondary prevention. In some cases, it also seems appropriate to support the diagnostic process with adequate mHealth tools.

A. Food Hypersensitivity

Adverse reactions to food intake can be roughly separated into two main branches: food allergy and and non-allergic food hypersensitivity. Non-allergic food hypersensitivity, also often named as food intolerance, refers to an abnormal physical response to a food or food additive, whereas (true) food allergy involves the immune system. Food allergy can be linked with a measurable increase of IgE antibodies or can be an immune response that is non-IgE-mediated [1][2]. Some non-allergic food hypersensitivities can be classified through missing enzymes for digestion (e.g., lactose intolerance), whereas others are related to the ingestion of colorants, preservatives or flavor enhancers. Through the involvement of the immune system, the reactions for food allergy can range from mild symptoms to life threatening events, like an anaphylactic shock. Although up to 35% of the German people believe they have adverse reactions to food, food allergy could only be confirmed for 4%, as an example of the western population [3]. The prevalence of lactose intolerance in Europe, for example, ranges from 4% in Denmark and Ireland up to 56% of the adult population in Italy [4].

The management of food allergies and food intolerances consists in educating the patient to avoid ingesting the respective allergen or food component. Some food intolerances allow a mitigation of the symptoms through medication (e.g., lactase), but the root cause can not be eliminated in most cases. As non-allergic food hypersensitivities can not be diagnosed easily using tests for the immune system, food intake diaries are of great value here. Also, for food allergy patients with complicated cases, food diaries help to identify individual allergens in the daily food.

B. Diabetes

According to the WHO Diabetes Fact sheet N312, ”346 million people worldwide have diabetes”. A 2002 study esti-

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mated the average annual costs per patient to EUR 2,834 in eight western European countries [5]. The goals of medical nutrition therapy for diabetes are to a) attain and maintain an optimal metabolic outcome (blood glucose levels in normal range, lipid and lipoprotein profiles as well as blood pressure levels that reduce the risk for complications of diabetes); b) prevent and treat chronic complications of diabetes through lifestyle changes; c) improve the health status through healthy food (and physical activity); d) address individual nutritional needs [6]. For overweight and obese individuals, a weight-loss diet, e.g., through low-carbohydrate or low-fat calorie-restricted diets, may be effective in short term. The scope of application for mHealth in diabetes II management is clearly the primary and secondary prevention as well as the disease management through food intake monitoring and dietary management.

C. Obesity

Obesity and overweight are major risk factors that are associated with several chronic diseases such as diabetes, cardiovascular diseases (CVD), hypertension, arthritis, some forms of cancer, or chronic kidney disease, to name a few. Based on the WHO classification, adults with a BMI from 25 to 30 are defined as overweight, and those with a BMI above 30 are obese. According to an OECD report, more than half of the adult population (50.3%) are overweight or obese, and across the entire OECD region, 17% of the adult population are obese [7]. These figures are even more dramatic when taking into account the predicted further rise, mainly among children, due to physical inactivity and cheaper and thus more easily accessible food in industrialized countries. Newest WHO figures presented in the Obesity Fact sheet N311 indicate that more than 1.4 billion adults in 2008 and more than 40 million children under the age of five were overweight in 2010.

D. Elderly Nutrition

Proper nutrition is essential for health and well-being, but it is often lacking among the elderly. For example, as the elderly reduce their food intake in response to decreasing physical activity, their iron intake also drops [1]. Apart from general nutritional needs of aged people, like increased calcium and vitamin D intake, often (co-)morbidities evolve that can be influenced through dietary behavior.

1) Neurodegenerative Diseases: Neurodegenerative diseases describe a group of conditions affecting the nervous system. Typical is the progressive loss of nerve cells leading to dementia and motion disorders. Popular examples include Alzheimer's Disease (AD) and Parkinson's Disease (PD). Alzheimer's Disease is becoming an increasing burden to the elderly population and very often displays symptoms like forgetfulness, lack of orientation, cognitive decline etc. A recent study found out that concentration of vitamin C and beta-carotene in the serum of AD patients was significantly lower than in control group [8]. In contrast to these findings, a correlation between quality of diet and the occurrence of Parkinson's Disease could not be detected so far [9]. Among subjects aged over 65, crude prevalence rates for dementia varied between 5.9% and 9.4% [10].

2) Malnutrition: Malnutrition is a quite common problem for elderly people. The consequences are a weak immune system, weaker muscle power, poor wound healing, tiredness and mental impairment, as well as less enjoyment of life. A body-mass-index (BMI) of 20 and below indicates malnutrition; if the BMI is below 18.5, the affected person is clearly malnourished. However, not only the BMI is a critical factor but also the supply with vitamin D, vitamin B12 and folic acid is essential, meaning that a person with a BMI above 20 still can be malnourished. In order to correctly assess a dietary condition, it is suggested to consider the weight loss in the past months, the mobility, autonomy of eating, number of main meals, drinking, and finally, the subjective state of health. Among other factors, appetite tends to decrease, leading to reduced food and nutrient intake. Other key risk groups are those with chronic diseases, people who are living in poverty or are socially isolated and those who have recently been discharged from hospital.

Recent research shows that only 17.7% of 80-year-old patients are well nourished, 58.7% are under risk of malnutrition and 23.6% of the patients suffer from malnutrition [11]. A study published in 2012 estimates the annual public health and social care costs associated with adult malnourished patients in Ireland at over EUR 1.4 billion, representing 10% of Ireland's health-care budget [12]. In Europe, an estimated 33 million people are at risk of malnutrition [13].

E. Raised Cholesterol

Raised cholesterol levels (LDL) are a major cause of coronary heart diseases (CHD) and are also strongly linked to diabetes. An LDL-lowering therapy reduces the risk of CHD. It should include therapeutic lifestyle changes accompanied by a drug therapy. The lifestyle changes include reduced intakes of saturated fats (<7% of total calories) and cholesterol (<200 mg per day), therapeutic options for enhancing LDL lowering, such as plant stanols/sterols (2 g/day) and increased viscous (soluble) fiber (10-25 g/day), weight reduction, and increased physical activity [14]. In Europe, the WHO assumes that about 54% of the population have raised cholesterol levels (above 190mg/dl, ages 25+).

III. Mobile Health (mHealth) solutions

The Mobile Health (mHealth) approach experienced a tremendous growth during the last years mainly propelled through the rising availability of mobile hardware, like smartphones and tablet PCs. Initiatives like "Quantified Self" pool self-tracking ideas for general life-style monitoring and tracking health-related data for general purpose. The range of available self-tracking tools encompasses solutions for

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tracking mood, physical activity, sleep, daily habits, food intake and many more. However, the ambitions of those tools are rather to be set in the voluntary self-management. The WHO Global Observatory report defines mHealth as "a component of eHealth" that is "medical and public health practice supported my mobile devices" [15]. The focus of the present paper lies mainly on mHealth tools that are oriented towards the management or prevention of concrete health conditions. Furthermore, the presented technologies rather center around the end users and attending health care professionals, in contrast to the use of mobile technologies within health care service provider organizations, e.g., in hospitals.

The rest of this section is divided into two parts, in which we firstly review condition-specific mHealth tools — concerning food sensitivity and diabetes — and secondly, evaluate more generic food information and diet management solutions currently available. Due to the space limitation, the authors renounce to mention references for the mHealth tools except for scientific papers. The presented approaches are examined with regard to their capabilities of a) providing food information, b) food intake monitoring, and c) diet management. Further, we distinguish between standalone tools and tools integrated in the health care chain with health care professionals.

A. *Condition-specific solutions*

1) Solutions for food hypersensitivity: As indicated in the previous section, the sole "treatment" of food hypersensitivities lies in the avoidance of the respective food allergen or food item. This is also the reason why most mHealth solutions in this specific area are limited to providing information about food items, whenever possible with relation to a patient-specific profile. However, the possibly life-threatening consequences of an unintended ingestion of an allergen due to a false negative rating by a mobile tool are always a huge risk for the user as well as to the solution-provider due to liability issues. Having this in mind, it is no surprise that most solutions are targeted towards non-allergic food hypersensitivity issues where no fatal consequences due to unintended ingestion are known.

Representative for non-allergic food hypersensitivity solutions, we present approaches covering lactose intolerance and gluten intolerance. Apps like **Laktosefrei** provide information about the contents of lactose in food products that have to be selected in a product hierarchy or through simple text search. The 900 products in Laktosefrei are a mix of generic food classes and branded food products. Other apps provide recipes for cooking lactose-free dishes and guidance for finding appropriate retailers and restaurants, e.g., in **Lactofree** (see Figure 1 left). In contrast to that, **Is that Gluten Free?** provides over 23,000 verified gluten-free products that can be easily searched (Figure 1 right), and **Gluten-free Scanner** uses the phone camera to scan the

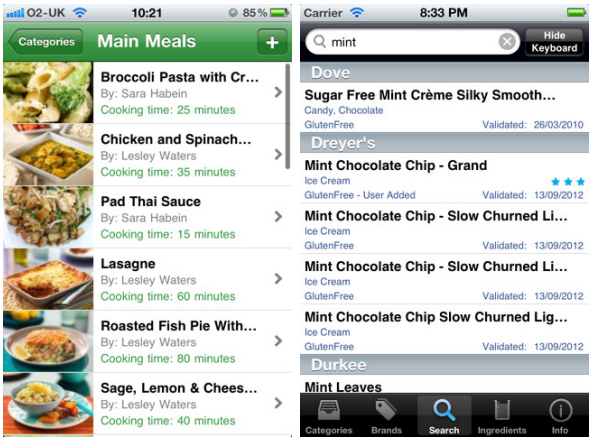

Figure 1. **Lactofree** and **Is that Gluten Free?**

barcodes printed on food packages. A few solutions try to cover multiple areas of food sensitivity. **Food Intolerances** covers histamine intolerance, fructose malabsorption, aspirin intolerance as well as lactose or gluten intolerance, but has only 700 commented foods, which is by far not a sufficient mass of data.

Most of the available food allergy-related solutions cover the requirement of providing information about specific products. There are more general apps that guide to allergy-friendly restaurants (**AllergyEats**) or provide information concerning food dishes available in specific restaurant chains (**Food Allergy Reference - Safe2EatTB4**). **MyFoodFacts** and **ScanAvert**, for example, use the built-in camera to scan the barcode of a food product and present information about the ingredients and possibly opposing allergens. The **FoodAllergy Detective** is an exceptional case as it does not focus on providing food allergy-relevant information to the end user, but it performs food intake and symptom monitoring in order to discover hidden food sensitivities. It should be noted that depending on the stated intended use of this app, it could be seen as providing a diagnostic method. If, however, it can be seen as such, it should have the approval as medical device, which is mandatory by law for such kind of functionality.

The major shortcoming of the presented solutions for food hypersensitivity is that they all are disconnected standalone tools. Thus, the authors want to share their experiences made during the progress of the MENSSANA project (Mobile Expert & Networking System for Systematical Analysis of Nutrition-based Allergies): The smartphone-based **Personal Allergy Assistant (PAA)** allows patients to keep an electronic diary by scanning the barcodes of the consumed food products. For diagnostic purposes, the diary is regularly transmitted to the allergist's electronic patient record. A computer-supported evaluation method for patient diaries has been developed and tested. To further support the individual diet management, the PAA gives a

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warning before consumption of allergenic food. Computer-readable food ingredient lists are required for the PAA diet management. To collect this kind of information, a dedicated web-based ”virtual community” of food consumers and producers (www.wikifood.eu) has been established. Clinical studies have been conducted to evaluate the usefulness of the MENSSANA-PAA approach. A total number of 26,916 diary entries for 28 patients have been transmitted via the telemedicine system. An average of 15.65 [4.49 41.27] entries have been reported per patient and day. It turned out that food diaries can be very helpful for diagnostic purposes if symptoms are in general linked with food intake. A time frame of eight weeks of self-monitoring is acceptable for most of the patients.

2) Diabetes: Mobile health applications and devices can support diabetic persons to better observe their diets through improved self-monitoring with reminders and alerts, and through generating diary information. This collected information can then be shared with the patient’s attending health care professional [16]. Typically, diabetes solutions encompass diary functionalities to record blood glucose levels, physical activity, and food intake. At the beginning of 2011, more than 260 diabetes-related apps have been counted in the iPhone app store, an increase of 400% compared to 2009 [17]. It can be assumed that online markets for other mobile platforms such as Android show a similar availability of diabetes-related apps. Prominent examples include the **BGStar** blood glucose meter and **iBGStar** blood glucose meter and iPhone app by Sanofi Aventis (Figure 2). Both are approved medical devices. The focus of (i)BGStar is the measurement and documentation of blood glucose levels, self-calculated carbohydrate intake, and administered insulin. Physical activities or food intake are only covered via configurable additional notes, such as ”high-fat meal”. Besides the calculated carbohydrate values and additional notes, the BGStar tools don’t allow for any more detailed food intake monitoring.

Another mentionable diabetes support tool is the **WellDoc Diabetes Manager**, which is an integrated mobile and online solution. It includes a message center, goal setting capabilities, information library, collecting glucose level with real time feedback on medicals, recording of where (part of the body) the injections are made, re-test reminder and a rather rudimentary food intake diary. Although WellDoc is a quite comprehensive system and shows a better decline of 1.2% of glycated hemoglobin compared to a conventional care group [18], the usability is lacking as the high drop-out rate of 50% in a study suggests [19]. A similar solution that is integrated with an online platform is **Glucose Buddy**. It also allows doctor printouts to be handed to the treating physician. Users can track glucose levels, carbohydrate consumption, insulin dosages, and activities. Standalone applications include **Actelin** and **iCholesterol**, for example, which mainly allow for diary keeping of glucose levels.

Figure 2. BGStar and iBGStar

B. Generic food information and diet management solutions

A major part of the available food-related mHealth apps are dedicated to diet management, especially aiming at weight loss and calorie counting. Many of these apps are associated with corresponding web communities dedicated to diet management and healthy nutrition. In addition to tracking the user’s food consumption, these apps often also offer the possibility to track further parameters, like physical activity, blood pressure, sleep, mood etc. A part of the apps use camera-based barcode scanning for identifying packed food products through their UPC identifiers. Clearly, these solutions require product information on individually packed food as printed on the corresponding product labels, in contrast to other apps, which use generalized food information related to food archetypes. Similar to the food sensitivity apps, the crucial point concerning the usefulness of diet management apps is the availability of appropriate food information databases.

Mobile apps like **LoseIt!** or **DailyBurn Tracker** allow users to specify their specific diet goals, log their daily food consumption using barcode scanning or through selecting food entries out of a food product hierarchy, and thus to keep an overview of their calorie consumption but also on the consumption of certain nutrients if needed. Similarly, **FitDay** allows the creation and management of personal food journals by choosing food items out of a predefined food hierarchy (without barcode scanning). This app aims at a long term analysis of the food journals and thus at supporting the users in gaining control over their eating habits. With the **iFood Diary** app, users can share their food diaries with their nutritionists via Facebook or e-mail. Apart from the possibility to chose food items from a conventional food hierarchy, the **GoMeals** mobile app additionally sets a focus on restaurant meals. Users can browse the menus of

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nearby restaurants and check the calorie and nutrient values of the offered dishes.

In addition to tracking their own food consumption, with the **alli Food Planner**, users can also plan their upcoming meals in accordance with their self-estimated individual calorie needs. This process is supported by corresponding meal suggestions by the app and a simple traffic light system indicating the appropriateness of certain foods. **CalorieTrack** is similar to the alli Food Planner but with automated calculation of calorie needs based on the user's current weight and height and the target weight.

The recently released **Food Navi** app calculates the optimal food intake in different food categories based on the user's personal profile and a special rating system - UGB's Healthy-Eating-Index (HEI-UGB). In contrast to other scoring systems, this index calculates the optimal intake amounts in different food groups, which are represented in the so-called nutrition circle, instead of being based on individual nutrients. The app is also available in specialized versions optimized for diabetics, coeliacs and cardiovascular prevention.

Beside these mobile apps which focus mainly on weight loss, there are also some apps that merely provide information on the nutrient values of food products without tracking the user's weight or calorie consumption. The app **Nutrition Facts** allows users to browse nutrition information for popular foods, including fast food. A similar functionality is offered by the app **MyFood - Nutrition Facts**, which however concentrates on unprocessed foods, like fruits and vegetables. The app provides complete nutrition data for a number of unprocessed foods, which includes a complete breakdown of vitamins and minerals. The food information app **Fooducate** automatically rates foods and beverages on a scale with 10 distinct grades based on their nutrition facts and ingredient lists. The information is presented in a clear and informative way, using different colors and simple labels. The user is also presented suggestions for alternative food products.

IV. Discussion

The previous section reviewed existing mHealth solutions from the viewpoint of food-related conditions and risk factors. It can be stated that a wealth of solutions for different aspects are available, e.g., apps for different smartphone architectures. However, their utility largely depends on further resources and requirements: a) availability of error-free information about food items and food products in order to be able to predict the tolerance or the usefulness of food for specific persons; b) the integration into a personalized case management process involving health care professionals.

Especially the data correctness is inevitable for conditions that can involve fatal consequences. However, for areas like obesity or other nutrient-based risks, rare data errors could be negligible in favor of an increased volume of available data. Two types of food information data are used: food-related information concerning archetypal food and information concerning specific food products. The archetypal information is most often drawn from food composition databases (FCDB) and includes averaged nutrition information for foods and food product classes. Digital food product-specific data, possibly extracted from food product labels, are not as widely available. For the US market, dedicated commercial databases of consumer packaged goods exist, but for the European dispersed multilingual markets, such databases are not available, apart from solutions available in the UK. Further, this type of data can be found at collaborative food information platforms, in which a community of users, manufacturers and platform operators maintains the data. Both sources of product specific data (commercial and community-based) implicate the question if the collected data is suitable for use in mHealth. This is due to the facts that commercial product information databases are mainly intended for business activities such as monitoring shopping behavior, and the quality assessment in community-based approaches is very often not addressed.

As shown in the previous sections, the presented diabetes solutions are better integrated into case management processes, and their main functionality covers diary keeping of blood glucose levels and food intake for documentation. The food intake is recorded by entering (self-calculated) carbohydrate values, but it is not based on archetypal food information or product-specific data. This is clearly an area where improvements are suggested. Apart from the diabetes apps and some further exceptions, most of the other presented solutions are standalone approaches providing the possibility to send data via email to a clinician at most.

Although not examined in detail in this article, we would like to finish the discussion by stating that a huge factor of uncertainty concerning mHealth solutions in general is the lack of evidence that undermines the quality and safety aspects of medical apps [20]. There is an ongoing discussion in the community of what a medical or health-related app is and how quality and safety characteristics can be guaranteed. In 2011, the U.S. Food and Drug Administration (FDA) initiated a regulation process for mobile medical applications, which has not been finalized yet [21].

V. Conclusion and Future Work

Food-related conditions and associated risk factors pose a dramatic burden to the society, which is expected to increase in the near future. Persons suffering from mentioned conditions can already choose from a wide range of mHealth solutions. However, certain weak spots have been identified: the functionality of the apps is limited to specific features, mainly displaying dietary information or collecting blood glucose levels for documentation. Menu planning or diagnostic support is most often not available. Moreover, the provided dietary information is frequently based on

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data coming from food composition databases and lacks information on specific food items sold in supermarkets. This is mainly true for the European sector. Further, dietary applications are often designed for general weight loss and not adjusted to specific risk factors, like raised cholesterol. Finally, a better integration of the solutions into case management processes is highly desirable. The latter and applied regulation processes for mobile medical applications will enable mHealth suppliers to provide solutions with a higher level of quality and safety, and will eventually allow additional functionalities, like diagnostic support.

Future work will include a more extensive review of actual user experiences of the target groups concerning app usage as well an assessment of number of users, age groups etc. and comments from health care specialists.

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