Computer Methods and Programs in Biomedicine 153 (2018) 93–104

Contents lists available at ScienceDirect

Computer Methods and Programs in Biomedicine

journal homepage: www.elsevier.com/locate/cmpb

DIETOS: A dietary recommender system for chronic diseases monitoring and management

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ARTICLE INFO

Article history:
Received 4 July 2016
Revised 2 October 2017
Accepted 10 October 2017

Keywords:
Food recommender system
Health profile
Foods database
Chronic diseases
Chronic kidney diseases

ABSTRACT

Background and objective: Use of mobile and web-based applications for diet and weight management is currently increasing. However, the impact of known apps on clinical outcomes is not well-characterized so far. Moreover, availability of food recommender systems providing high quality nutritional advices to both healthy and diet-related chronic diseases users is very limited. In addition, the potentiality of nutraceutical properties of typical regional foods for improving app utility has not been exerted to this end. We present DIETOS, a recommender system for the adaptive delivery of nutrition contents to improve the quality of life of both healthy subjects and patients with diet-related chronic diseases. DIETOS provides highly specialized nutritional advices in different health conditions.

Methods: DIETOS was projected to provide users with health profile and individual nutritional recommendation. Health profiling was based on user answers to dynamic real-time medical questionnaires. Furthermore, DIETOS contains catalogs of typical foods from Calabria, a southern Italian region. Several Calabrian foods have been inserted because of their nutraceutical properties widely reported in several quality studies. DIETOS includes some well known methods for user profiling (overlay profiling) and content adaptation (content selection) coming from general purpose adaptive web systems.

Results: DIETOS has been validated for usability for both patients and specialists and for assessing the correctness of the profiling and recommendation, by enrolling 20 chronic kidney disease (CKD) patients at the Department of Nephrology and Dialysis, University Hospital, Catanzaro (Italy) and 20 age-matched healthy controls. Recruited subjects were invited to register to DIETOS and answer to medical questions to determine their health status. Based on our results, DIETOS has high specificity and sensitivity, allowing to determine a medical-controlled user's health profile and to perform a fine-grained recommendation that is better adapted to each user health status. The current version of DIETOS, available online at http://www.easyanalysis.it/dietos is not intended to be used by general users, but only for review purpose.

Conclusions: DIETOS is a novel food recommender system for healthy people and individuals affected by diet-related chronic diseases. The proposed system builds a users health profile and, accordingly, provides individualized nutritional recommendations, also with attention to food geographical origin.

1. Introduction

The positive correlation between obesity and cardiovascular mortality, all-cause mortality, and the risk of cardio-metabolic diseases has been widely reported and is a diagnostic variable for metabolic syndrome. Diet-related diseases are, consequently, the most common cause of death worldwide and are associated with an excessive sature fat acids, animal proteins and/or free sugars intake [1–6].

A prototype of diet-related disease associated with high cardiovascular morbidity and mortality is chronic kidney disease (CKD) [7–10]. CKD is characterized by a progressive and irreversible loss of kidney function that, however, is accompanied by blurred symptoms until the hypertrophic residue renal tissue fails to deliver the clinical compensation [11]. The main determinants of CKD and

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https://doi.org/10.1016/j.cmpb.2017.10.014
0169-2607/

its progression are hypertension and diabetes, themselves clinically silent [11].

The unawareness of being hypertensive, or diabetic or affected by CKD represents the main obstacle to interfere the progression of renal damage and to prevent the occurrence of its complications [12]. Therapeutic diet regimens have been individualized for different disease stages according to Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines [13]. The clinical profiling represents a fundamental tool for a correct management of the diet in this typology of patients while the monitoring of clinical responses and compliance to the prescription is the major mission of nephrologists and nephrology-dedicated nutritionists.

New communication technologies could benefit the collection of food intake data and, generally, dietary monitoring and diet-related chronic diseases management. In [14], authors highlighted how text messages, smartphone apps, and web-based programs could have positive impacts on users behaviors. There is a wide proliferation of nutrition related web and mobile applications, but further research is necessary to assess the effectiveness of apps for weight and diet management [15,16], that lack of evidence-based contents. Moreover, computer vision, video games, wearables and augmented and virtual reality appear potentially useful to support dietary and weight monitoring [17]. However, at the best of our knowledge, none of available systems combine together health profiling, specialized dietary advices with attention to food geographical origin, clinical and compliance monitoring in users affected by chronic diseases. Despite few research projects have presented food recommender systems (RS) addressed to diabetic or CKD users, they missed to consider all aspects necessary for a correct dietary and clinical management.

In this paper, we present the optimized architecture and functionalities of a web-based Recommender System (RS) called DIETOS (DIET-Organizer System). In two previous papers [18,19], we presented early versions of DIETOS. Current DIETOS form contains several innovative aspects:

- The methodology provides individualized nutritional recommendations according to user health profile obtained through the administration of medical questionnaires provided by nutrition specialists and nephrologists and accomplishing to World Health Organization and KDOQI guidelines.
- The ability to profile not only healthy users but also patients affected by CKD, hypertension and/or diabetes. Furthermore, CKD users are provided with glomerular filtration rate estimation by Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula for disease staging.
- To the best of our knowledge, DIETOS is the first RS containing a catalog of typical regional foods characterized by nutraceutical properties. Also, the system is modular, and the food database can be promptly extended with new products. As strength point, based on his/her health profile, DIETOS provides user with Calabrian typical foods benefits and side effects.
- Conversely to conventional RSs in which user health profiling is based only on a generic behaviour data entry by the user, in DIETOS a high quality health profiling is achieved because the user has to provide several clinical measurements (e.g., creatinine, blood glucose, blood pressure).

The paper is organized as follows: in Section 2 we describe the state of the art related to existing web systems and mobile apps for dietary monitoring and management. In Section 3, a detailed description of DIETOS architecture and functionalities is reported. In Section 4, is outlined a pilot study conducted on a cohort of CKD patients and healthy subjects and it presents the experimental results in terms of collected variables and systems calculated performance parameters. Section 5 discusses the DIETOS results and compares the systems features to similar systems, highlighting advantages and innovative aspects of our system. Section 6, finally, draws the future work planning and conclusions.

2. Related work

Nowadays there is a widespread diffusion of web and mobile applications (apps) for weight and diet management. These applications help users to choose for healthy food, log his/her nutrition intake and pick and choose a healthy diet plan. Many of these systems provide information about macronutrients and micronutrients. Others have been designed to help users to find recipes that reduce health risks and food sensitivities, create grocery lists, and engage in other aspects of the meal plan. Moreover, novel RSs include video games, wearables, and augmented and virtual reality that demonstrate potential to support dietary and weight monitoring. In [20], authors propose a goal-based slow-casual game approach that addresses the need for an intervention that educates the public on how to make healthy choices while eating away from home. u-BabSang [21] is a RS that provides individualized diet advices in real time, while the user is at the dining table.

Even though mobile and web-based applications for weight and diet management are increasingly used, the quality of these apps remain not well-characterized [22,23]. They are not usually experimented in clinical contexts, as well as they are not supported by medical evidence, and most of them do not include the behavior change techniques (BCTs) [24,25].

Moreover, as pointed out by [26], the general focus of these systems is on weight loss and calories counting. Personalized nutrition recommendations are quite limited, and they do not take into account the quality of foods consumed.

An interesting comprehensive review is [27]. Authors analyze quality and BCTs of popular weight management apps available on both iTunes and Google Play. App quality was measured through the MARS scale [28] that explores engagement, functionality, aesthetics and information reliability. Overall, popular apps showed moderate quality, but scored higher in terms of functionality and aesthetics. Self-monitoring and provision of feedback were the BCTs most frequently identified in different apps. Similarly to other reviews, authors stated that apps generally lack of experimental validation.

In [29], authors evaluated feasibility and short-term efficacy of a mobile phone app in the prevention of diabetes onset in overweight English-speaking adults. The mobile app included electronic diaries for weight, physical activity and calories intake self-monitoring, supported by daily reminders to enter data and providing weight loss as a primary outcome. Text messaging and mobile apps were therefore found to be promising tools for delivering weight loss interventions and achieving clinically significant weight loss in overweight adults.

Conversely, another systematic review aiming to investigate the benefits of dietary mobile apps in dietary intake and clinical outcomes in the renal population, has been presented in [30]. Of 712 studies considered, only five were eligible for inclusion in the review and only two were randomized controlled trials (RTCs). Based on their literature analysis, authors concluded that the use of dietary mobile apps does not allow to reveal notable changes in nutrient intake, biochemical markers or weight gain. Furtermore, the need for additional rigorous trials with larger sample sizes to determine the effectiveness of dietary mobile app intervention was highlighted. Also, authors recommended the use of high-quality apps preferably including advices on local foods.

Moreover, at the state of our knowledge, these apps do not are devoted to users affected by diet-related chronic diseases, such as hypertension, diabetes or CKD. In literature, few dietary systems dedicated to chronic diseases are proposed as research projects.