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# Computer Methods and Programs in Biomedicine

# Developing a ubiquitous health management system with healthy diet control for metabolic syndrome healthcare in Taiwan

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A R T I C L E  I N F O

A B S T R A C T

*Background and Objective:* Self-management in healthcare can allow patients managing their health data anytime and everywhere for prevention of chronic diseases. This study established a prototype of ubiquitous health management system (UHMS) with healthy diet control (HDC) for people who need services of metabolic syndrome healthcare in Taiwan.

*Methods:* System infrastructure comprises of three portals and a database tier with mutually supportive components to achieve functionality of diet diaries, nutrition guides, and health risk assessments for self-health management. With the diet, nutrition, and personal health database, the design enables the analytical diagrams on the interactive interface to support a mobile application for diet diary, a Web-based platform for health management, and the modules of research and development for medical care. For database integrity, dietary data can be stored at offline mode prior to transformation between mobile device and server site at online mode.

*Results:* The UHMS-HDC was developed by open source technology for ubiquitous health management with personalized dietary criteria. The system integrates mobile, internet, and electronic healthcare services with the diet diary functions to manage healthy diet behaviors of users. The virtual patients were involved to simulate the self-health management procedure. The assessment functions were approved by capturing the screen snapshots in the procedure. The proposed system development was capable for practical intervention.

*Conclusion:* This approach details the expandable framework with collaborative components regarding the self-developed UHMS-HDC. The multi-disciplinary applications for self-health management can support the healthcare professionals to reduce medical resources and improve healthcare effects for the patient who requires monitoring personal health condition with diet control. The proposed system can be practiced for intervention in the hospital.

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## 1. Introduction

"An ounce of prevention is worth a pound of cure – by Benjamin Franklin." Many prior studies for healthcare encouraged the self-health management programs of chronic diseases to improve health status of patients and reduce financial cost of hospitalization [1–3]. Those programs educated the patients in prevention knowledge and healthcare skills of perceived illness for diet control, medication care, behavior measurement, risk assessment, etc. [4]. They achieved the ubiquitous health management system (UHMS), which involves electronic, internet, or mobile interface in a computerized architecture, for the patients to manage their health information everywhere by themselves from day to day [5–7]. Thus, the healthcare providers can evaluate patient-reported outcomes and clinical records efficiently by combing the UHMS and the hospital information system (HIS) to monitor health status of patients.

Many chronic diseases and digestive illnesses are related to improper diet habits. In the last decades, the dietary patterns trended to energy-dense diets that are high in saturated fat and low in unrefined carbohydrates because of changes in the world food economy. Eating behaviors of people in the modern countries usually accompany with a sedentary lifestyle, which declines in expenditure of energy, and potentially increase risks of metabolic syndrome, obesity, diabetes, and cardiovascular diseases, etc. [8–12].

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The earlier studies explored that millions of people in the United States of America (USA) are sick with foodborne disease every year and total over billions for the cost in lost wages, insurance claims and medical bills [13,14]. In the recent years, the consecutive foodborne disease outbreaks have gained attention of the national centers of disease control and prevention (CDC). Therefore, they suggested the guidelines of food safety and healthy diet, particularly for the dine-out groups [15–19]. For example in the USA, the government has approved a dietary tracking program to help people managing personalized nutrition and physical activity plan [20]. In Taiwan, people in the dine-out group would expect personalized dietary guidelines that allow monitoring the risk indexes such as obesity, high blood pressure, high triglyceride, high fasting glucose, and low high-density lipoprotein cholesterol (HDL-C), for prevention of chronic diseases relative with metabolic syndrome [21–24].

The dietary guidelines can help the individuals taking healthful diet based on personal health condition to control healthy weight, promote health, and prevent chronic disease. The architecture of a UHMS for personalized diet requires dietary health database and self-health management interface that can be connected with the legacy HIS for clinical decision support and healthcare supervision [25–27]. Both of daily diet data and personal health information, which are complied with the relational database scheme, would enable the system to store categories of foods, additives, nutrition, and toxin; thus, the criteria of dietary risks and health baselines can be defined with respect to the specific diseases [28–34]. In addition, interface of the ubiquitous management would contain a variety of portals to support smart health with the mobile-enabled and Web-based applications. The studies for smart health design web and mobile applications, which can provide self-observation and measure behavior change for the users, to reinforce health awareness of possible patients [35,36]. For instance, the design may include diet diary function, health assessment, information management, and analytic diagram in the healthcare system that can be built on electronic, internet, or mobile infrastructure (i.e., eHealth, iHealth, or mHealth) for offline and online operating modes [37–41]. Therefore, the major scope of the UHMS would target to manage self-recordable dietary data and assess individual health baselines anytime and everywhere for controlling diets and preventing diseases. The previous studies have agreed positive effects of the self-management program on eHealth service but expected a self-established platform with expandable framework and collaborative components [42–44].

In this study, we developed a prototype of the Web-based and mobile-enabled UHMS with healthy diet control (HDC) functions for self-health management services to support prevention of chronic diseases in Taiwan. The present functionality was limited to monitor the typical diet records regarding metabolic syndrome. The design and development processes for generating the proposed UHMS-HDC are detailed in the method section of the present paper. Subsequently, implementation and performance of the system is demonstrated in the results sections. Some virtual patients, which are based on de-identified electronic health records in HIS to simulate functionality [45], are included for system evaluation. Finally, the discussion and conclusion sections describe the experiences with the comments for the approach.

## 2. Methods

The proposed UHMS-HDC was developed by open-source Java technology. The system enables mobile-enabled and Web-based interfaces, which were constructed respectively on Android platform and Apache-Tomcat server, to collaborate with MySQL database freeware for processing the self-health management records. Infrastructure of the UHMS-HDC comprises three portals and a database tier to transform health information by Web services

(WS) over Internet protocols. The prototype of the self-developed UHMS-HDC enhances the ubiquitous services in medical and health care for the dine-out people to manage daily diets and assess metabolic syndrome risks by themselves. The present HDC functions involve: (1) mobile diet diary, (2) online health assessment, (3) diagrammatical nutrition information, and (4) health data analysis for clinic support. The design methods for developing the Web-based interface "HealthControlWeb" and the mobile applications (Apps) "HealthControlApp" are addressed below.

### 2.1. Infrastructure design

The UHMS infrastructure as shown in Fig. 1(a) consists of three multi-disciplinary portals, which support mHealth, iHealth, and eHealth controls, upon a database tier, which stores diet, nutrition, and personal health baselines, to achieve the self-management services including diet diary, health management, and medical care support. The development utilized the model-view-controller (MVC) design pattern, which complies with standard enterprise software architecture, to conceptually assign the components to the roles of the functional organs, the sensible receptors, and the logical brain (i.e. model, view, and controller, respectively) for mutually collaborating the objects in multiple layers [46]. In this approach, it enables reusability of the HDC functions for a variety of the portals that communicate with the patients, medical care providers, and research professionals.

#### 2.1.1. mHealthControl portal for diet diary

The portal of mHealth control uses the mobile devices, such as smart phone, tablet pad, and laptop, to acquire daily dietary data that can be stored into the system through Internet. The design of mobile Apps requires simple-touch interface for the portal in which the users can easily catch the suitable meal and write the diet diary at mealtime. The dietary data can be transiently saved in the memory card of the device at the offline mode until internet is available (i.e. the online mode) for uploading the data to the database server. Thus, the personalized health risk criteria of the users can be updated and saved in the mobile device for tracing daily diets.

#### 2.1.2. iHealthControl portal for health management

The portal of iHealth control provides Web-based interface for the users to manage their personal health information through the UHMS. The system offers self-health management functions including diet diary, nutrition diagram, health risk assessment, self-health baseline, healthcare education, and medication knowledge. These functions serve online information of diet and health to support interactive mechanisms for ubiquitous management. The users can manipulate the electronic records related to their health on the Web. In addition, they can administrate their individual baseline data according to the personalized dietary guideline that is helpful to efficiently assess the potential risks for self-health management upon the diagrammatical interface.

#### 2.1.3. eHealthControl portal for medical care

The portal of eHealth control assists the healthcare providers monitoring the management data and allows the researchers maintaining the system. This portal needs administration privilege to accompany other two portals for the maintenance. It can connect the UHMS platform with the HIS for acquiring medical care feedback from the professionals who can monitor the healthcare management in clinics. They, if authorized, can update medical care information for remote consultant through the HIS interface. The WS schemas are designed in the system for transforming cross-interface data in unified format and integrating the advanced functions with flexibility. Thus, the expertise can suggest the personalized dietary rules for the users by exchanging the health criteria