The Dietary Intake Monitoring System (DIMS) - an Innovative Device for Capturing Patient's Food Choice, Food Intake and Plate Waste in a Hospital Setting

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Abstract

Portable intelligent devices offer a number of opportunities to collect accurate dietary data for the convenient assessment of food choice and food intake. In this paper we describe a Dietary Intake Monitoring System (DIMS) as a device for capturing accurate data on a patient's meal both before and after consumption in a hospital setting for the assessment of food choice, food intake and plate waste. The DIMS consists of a digital camera, weighing scale, infrared thermometer, radio-frequency identification (RFID) reader, and a user RFID transponder card. The digital camera and weighing scale captures a digital photograph and measures the weight of content on a patient's plate before and after consumption. The temperature of food prior to consumption is also recorded with the aid of an infrared thermometer. Based on these inputs the DIMS gives an account of the amount of food on the plate as well as of the serving temperature of it. The DIMS prototype offers new opportunities to improve dietary data collection, routine monitoring of meal temperature and patients nutritional intake in hospital settings.

Keywords: Food choice, plate waste, food intake, hospital setting, RFID technology

Introduction

The nutritional well-being of hospital patients depends mainly on the nutrient intake from meals served by hospital foodservice. Undernutrition is a well-documented problem in hospitals around the world [1, 2]. A hospitals is a setting in which routine dietary monitoring can be of tremendous benefit and contribute positively to patient nutrition therapy, with a positive influence on foodservice quality and patient recovery [3,4]. Effective routine monitoring of patient food intake may depend on the availability of accurate dietary data, at the ward level. A major challenge is finding an appropriate method for the collection of accurate dietary data for large number of patients at nutritional risk, which can also reduce the workload involved in capturing the data. The method chosen is often influenced by the type of device, tool, or equipment to be used. For instance, when adopting a food photographic method for recording dietary data, the device required may vary from that of the weighing method. Although the weighing method is considered accurate, conducting it with the required tools and equipment for large numbers of patients can be very time consuming, costly and obstructive to the proceedings in a hospital setting [5].

The use of technological applications in dietary assessment methods have simplified the process and enhance the acquisition of data for the assessment of food choice, food intake and plate waste analysis [6, 7]. Technological innovations in digital cameras and communication devices that are able to collect dietary data in the form of digital images, have led to the development of a method for estimating food intake, that uses images of food choice and plate waste [8, 9]. It is possible to apply image process techniques or image analysis for recognizing food items from the digital photographic image estimate the weight of each food item and convert those input into calorie and nutrient values, from food composition databases [10, 11]. Estimating portion sizes based on images can induce errors, however incorporating the actual weight of a portion, has the potential to improve the accuracy of this approach [12]. This approach requires an innovative device that can capture and provide both serving size weights and digital photograph images to provide accurate dietary data. However, the availability of an innovative device that can combine both weighed and digital photography methods of collecting dietary data in a single device based on cutting edge technology is still in its infancy and the accuracy, convenience and feasibility of such a device is a considerable challenge. This gap in technology performance constitutes the background for the current study. Researchers, hospital and clinical nutrition professionals as well a Danish small- and medium-sized enterprise (SME) were involved. In this paper, we describe the Dietary Intake Monitoring System (DIMS) and its basic technologies, as well as the technique used for capturing accurate data of a patient's meal before and after consumption for assessing food choice, food intake and plate waste. In addition we present a pilot study, in which we tested the feasibility of the DIMS in a hospital setting for collecting and analyzing patient's food choice, intake and plate waste.

Description of Key Components of the DIMS

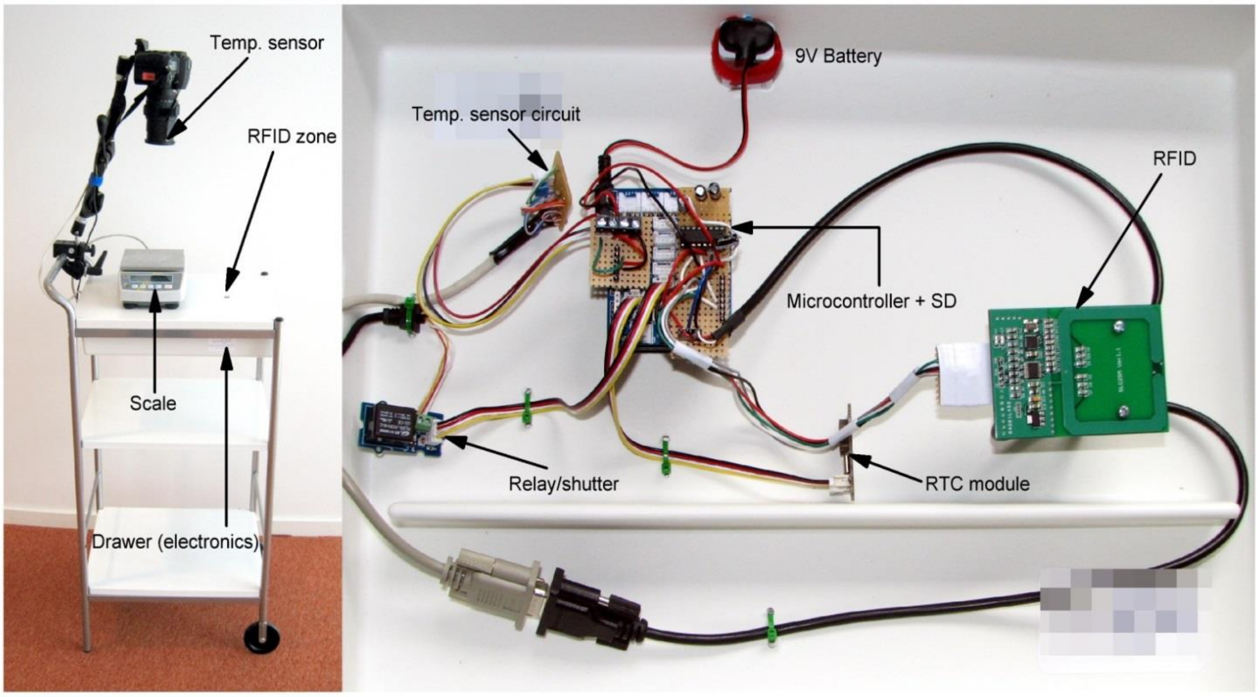

Figure 1. The DIMS Prototype Setup and Components

The DIMS prototype is built around an ATmega328 microcontroller that interfaces a shutter control relay, digital scale, radio-frequency identification (RFID) reader/writer module, infrared thermometer, real-time clock (RTC) module and a secured digital storage card for data collection. The heart of the system is contained in this single-chip microcontroller. The firmware for the microcontroller has been written in C computer programming language. The microcontroller and the sensors are powered by one 9V battery. It does not require external power lines; this increases DIMS's mobility and versatility.

Radio-Frequency Identification (RFID) Transponder Card

The RFID transponder card is coded with an identification number and links collected data to the patient. Since RFID numbers are unique, each patient is assigned one personal RFID transponder card. RFID is a contactless technology and can therefore also be used in situations where direct contact is not possible or not desirable. Many hospitals, other than those using traditional 1D and 2D barcode systems use wristbands with built-in RFID transponders. This makes the data collection process even easier although special care should be given to patients' privacy.

Digital Camera

A general purpose digital camera is used as the image capturing device for the DIMS setup. The aim of this special design is to minimize the amount of specialized equipment that has to be carried around when conducting on-site data collection. The camera is held on a special arm to allow for flexible positioning as shown in Figure 1. The camera is set to a high resolution in order to produce pictures that can enhance further analysis. In the DIMS setup the shutter has been configured to take approximately three pictures per plate over a period of 3 seconds. The shutter fires automatically once the weight on the scale has stabilized. Pictures are saved to camera's secured digital storage card and can be retrieved later for further analysis by the investigator.

Weighing Scale

The DIMS uses a certified trade digital scale (range 0-6000g, d = 1g) equipped with a RS232 data port so that the weight readout is automated. Weight data from the scale as well as other parameters are stored on DIMS's internal secured digital storage card. The digital scale takes on average 3 seconds to stabilize. Therefore all additional data acquisition processes are designed to be fast in order to keep the total time (per sample) very low.

Real-Time Clock (RTC)

The Real-Time Clock (RTC) component provides accurate time and date information for the system. It is also used as a key to data linking.

Infrared Thermometer

The infrared thermometer component of the DIMS was added since meal temperature is an important part of the patient's perception of meal quality and since sub-optimal temperature might be a food safety issue. It measures the average temperature of the food from a distance without having physical contact with the patient's food. The infrared thermometer face is directed towards the surface of the plate content, from which the average temperature of the food is determined by measuring the intensity of the infrared energy that accompanies the food. This feature can furthermore be used for routine meal quality assurance purposes.

DIMS Application

The DIMS application contains a simple piece of software that automates the process of data organization. It groups image files and joins them with the data collected from various sensors (RTC, RFID, and thermometer).

Measurement Procedures before and after Food Consumption for Plate Contents

The process for measurement has been designed with simplicity and speed in mind so that unnecessary delays in food serving are avoided. The measuring process can be described in four points:

1. RFID transponder card is placed onto the RFID reader active zone.
2. The plate is placed on the scale.
3. As soon as the weight stabilizes the system simultaneously takes pictures and collects other corresponding information on weight, temperature, date and time.
4. The plate and the RFID transponder can be removed. The system is ready to record another measurement.

Image data is stored on the camera's storage system whereas date, time, weight, temperature and RFID number are stored on the internal storage attached to the microcontroller of the DIMS. Once the data acquisition session is over, it is the investigator's responsibility to retrieve all the stored data onto a personal computer and run DIMS application.

Pilot test in a hospital setting

Methods

The DIMS was pilot tested in a medical gastroenterology ward. In this ward patients can choose their meals directly from the food trolley and be served by healthcare staff. We collected data at supper meal sessions for 3 days on three separate occasions. Our research contact person at the hospital identified potential patients for the study. The meals of twenty three participants were recorded in this study. Prior to the measurements we briefed the participants on the purpose of study and each was given a RFID transponder card. The principal investigator followed the 4 steps outlined in the measurement procedure for recording content on a patient's plate before and after consumption. The study was approved by the Local Scientific Ethics Committee and all patients gave oral informed consent.

Results and Discussion

The data was analyzed in the DIMS application, which created twenty three matched folders with photos of the content on a patient's plate before and after consumption. The DIMS application automatically generates a name for each folder by using patient's RFID code, date and time of measurement. We analyzed the each folder with the corresponding weight to deduce patient's food choice, plate waste, food intake and the food temperature before consumption as shown in table 2. In our pilot test we found that the DIMS is applicable for capturing photo images and measures the weight of content on a patient's plate before and after consumption in less than 4 seconds. The process does not obstruct meal servings at the ward. The process of matching before and after measurements, if done manually, will be tedious and subject to errors. However, with the DIMS application software, matching of before and after consumption data for each patient was less time consuming. Using the photo and weight data we were able to obtain vital information helpful to understand how much patients do throw away on the ward, food choice preference and intake. The goal of this paper was not to test DIMS for automatic estimation of energy and nutrient intake, since the DIMS application software is being developed to recognize food items from the image and estimate the weight. The data available from the DIMS indicates that the weight can improve the accuracy of estimating portion size from photo images for energy and nutrient intake calculation. This is because the total weight of all food items estimated from a photo can be equated to the actual total weight measured by the DIMS. To the best of our knowledge, no study has reported on the reliability and validity of a method that concurrently uses both photo and weight to estimate food choice, intake and plate waste. Therefore such research will be helpful to decide the appropriateness of using DIMS as method in a hospital setting

Table 1. Shows food items chosen and served on the study days.

Meal Session	Day 1	Day 2	Day 3
Supper	Gullasch (GH) Mashed potatoes (MB) Parsley with red onion (PO) Potatoes small /spiced (PS)	Manogryde (MG) Fish (FH) Mashed potatoes (MP) Parboiled rice (PR) Hollandaise sauce (HS) Bacon tern (BT) Broccoli salad with pumpkin seeds (BP) Mayonnaise (MY) Butter (BU)	Chili concarne (CC) Mashed potatoes (MB) White sauce (WS) Carrot salad (CS) Fish cakes with herbs (FC) Potato / whole vaccum precooked (PP) Lingonberry jam (LJ) Butter (BU)

Table 2. Shows patient's food choice, plate waste, food intake and the temperature of food before consumption.

RFID code	Food items on plate before consumption (total food items)	Total food weight before consumption (g)	Temperature of food before consumption (C°)	Food items on plate after consumption (total food items)	Total food weight after consumption (g)	Plate waste (%)	Total food intake (g)	Total food intake (%)
a0789086	GH,MP, PO (3)	441	23,6	GH,MP,PO (3)	122	27,6	319	72,3
10a28e86	GH,MP,PO,AC (4)	358	24,0	(0)	0	0	358	100
90b59286	GH,MP,PO (3)	274	23,2	GH,PO (2)	54	19,7	220	80,3
80509386	GH,PO,PS (3)	379	23,1	PO,PS (2)	91	24,0	288	75,9
c0dc8e86	MG,PR,MY,BT,BP(5)	296	24,0	(0)	23	7,8	273	92,2
602b9086	FH,MP,HS,BT,BP(5)	430	23,3	(0)	0	0	430	100
c0279386	MG, PR,BP,MY(4)	202	23,8	MG,PR,BP,MY(4)	146	72,2	56	27,7
a0b49286	FH, PR,HS (3)	206	23,7	(0)	0	0	206	100
e0399386	FH, MP, HS,BT(4)	265	24,6	(0)	0	0	265	100
40ba9286	MG,PR,BP,BT,MY(5)	256	23,1	MG,PR,BP,BT,MY(5)	208	81,3	48	18,6
20f08f86	FH,MP,BU (3)	272	24,3	FH,MP(2)	157	57,7	115	42,3
a00d9186	FH,RP,HS,BT(4)	178	23,9	FH,RP,HS,BT(4)	160	89,9	18	10,1
e0be9286	MG,MP(2)	112	23,5	(0)	0	0	112	100
60b79286	MP,CC(2)	265	24,5	CC(1)	38	14,3	227	85,7
50319386	FC,MP,WS(3)	193	25,0	WS(1)	30	15,5	163	84,5
c04c9386	FC, MP,WS,CS(4)	270	26,2	(0)	0	0	270	100
d04c9386	FC, MP,WS,LJ(4)	302	25,7	(0)	0	0	302	100
80eb8f86	FC,MP,WS(3)	329	23,8	WS(1)	20	6,1	309	93,9
604e9286	FC, MP,WS,CS(4)	310	26,3	FC, MP,WS,CS(4)	244	78,7	66	21,3
504f9286	FC, MP,WS,CS,LJ(5)	264	24,3	FC, MP,WS,CS,LJ(5)	245	92,8	19	7,2
c0009386	FC,PP,WS,CS(4)	322	24,2	FC,PP,WS,CS(4)	117	36,3	205	63,7
20d98e86	FH,MP,CS,BU(4)	318	24,7	FH,MP,CS,BU(4)	132	41,5	186	58,5
904b9387	FC,MP,WS(3)	267	24,8	(0)	0	0	263	100
Mean	(4)	283	24,2	(2)	78	27,5	205	72,5

Conclusion

We have developed DIMS which is easy to use, and despite being in the prototype phase, requires less time to capture food choice, intake and plate waste in a hospital setting. This has been possible through a technology that integrates a digital camera, RFID sensor, weighing scale and infrared thermometer. The RFID technology provides more possibility to link data from the DIMS with other patients' information systems considered relevant for dietary assessment. Furthermore we are developing the DIMS application software for automatic recognition of the food items from the image, estimate the weight and convert into calorie and nutrient values from food composition databases. We believe that this technology can lead to a new methodological approach for collecting data for dietary studies and in particular to improve the monitoring of nutritional intake in hospitals.

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