Diet Advisory System for Children Using Biofeedback Sensor

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***Abstract*—Measuring energy expenditure has a significant role in health monitoring systems. It provides vital information about physical activities that are essential indicators of wellbeing, especially for children. Biofeedback systems are promising methods to monitor and measure daily energy expenditure. In this paper, we present a diet advisory system using biofeedback sensors to monitor children physical activities and estimate the consumed energy, which can be utilized to provide diet recommendations, based on children's health records and preferences, to the parents to improve the children's health status. We propose an algorithm to calculate daily energy expenditure for children based on the accelerometer sensor. This system aims to promote healthy food habits in accordance with energy expenditure, vitamins, and allergies. The system evaluation has demonstrated the ability of the proposed system to provide useful recommendations about the children diet habits for the parents while adopting to the children's health record and preferences and avoiding allergic food.**

Keywords-component; Health care; accelerometer sensor; biofeedback systems; energy expenditure;

I. INTRODUCTION

Physical activity of children is the first indicator for their health status. It determines the daily energy consumption, which in turn determines child's activity level. Imbalance in physical activity level causes energy consumption disorder in child's body, which then contributes in the occurrence of dangerous diseases such as obesity, or hyperactivity disorder [1]. Daily diet is considered a fundamental factor that affects child's physical activity level and eventually the wellbeing of the children [2].

Nowadays, monitoring the daily diet of children and determining proportional activity levels is a real challenge due to several reasons. First of all, there is a wide range of fast food options, which attracts both parents and children although they lack nutrition qualities; second, children spend most of their day at school, which makes monitoring of physical activity level a hard task for the parents. Therefore, it is the responsibility of parents to prepare meals that suit their children and keep them healthy, and avoid diseases such as obesity and encourage them to practice healthy food habits.

In this paper, we propose a personalized biofeedback system that measures the daily energy expenditure using an accelerometer that measures the children level of activity and suggest food intake accordingly while taking child's allergic reactions into consideration. The purpose of applying this algorithm is to facilitate the decision making process for parents regarding which food must be included in a child daily meals. In fact, the system will provide various food recommendations for each meal with several alternatives to satisfy child's preferences and availability of food. The biofeedback system obtains measurements from the accelerometer and applies the energy consumption calculation algorithm to determine child's activity. Then, the system provides food recommendations that fulfill child's body needs on daily, weekly or even monthly basis.

The rest of this paper is arranged as follows: section II presents the related work on the measurement of children activity using accelerometers as well as diet advisory systems for children. Section III describes the proposed system merits and presents the details of the energy expenditure computation. The system implementation and a demonstration example are presented in section IV. Finally, section V concludes the paper and provides perspectives for future work.

II. RELATED WORK

In this section, we present a brief review of the accelerometers usage in measuring children physical activity level.

Many researches have been dedicated to measure physical activity, which is a significant factor for health and fitness by using accelerometers. Accelerometers are favorites over competitor methods (such as the doubly labeled water (DLW) technique [3]) due to their abilities to provide direct observation and writing diaries for daily physical activities. Furthermore, accelerometers are an objective measure of routine activity that is independent from self-report, and are better than pedometers because they measure the intensity of physical activity as well as frequency [4].

In fact, several researches have special interest in children health care area especially addressing the obesity issue. Evaluating children's physical activity is a challenging task with research that uses questionnaires and diaries as information resources [5]. However, the deployment of accelerometers for measuring children physical activity provides an objective method as they are measuring the intensity and the period of child's activity as well as the

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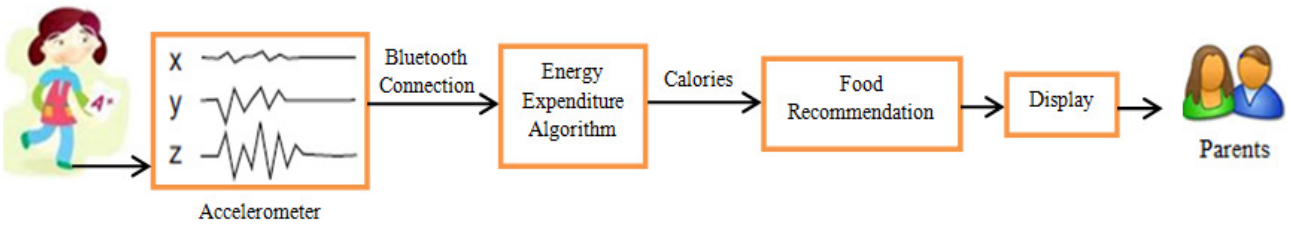

Figure 1. Food recommendation system using a biofeedback sensor (Accelerometer).

frequency [5]. A well-known accelerometer for this purpose is the Actigraph (officially MTI and CSA), which is small, non-obtrusive, and robust and does not have external screen or buttons that makes it optimal with competitive children although there are many accelerometers available commercially [5].

Moreover, there are many studies concerned about the deployment of accelerometer to measure children's' physical activities. Researchers in [5] use Actigraphs with around 100 pre-pubertal children in India to explain the level and pattern of physical activity for those children. They found that the activity level recorded by the Indian children was lower than the European children, which is recorded by other researchers. Also, there are several challenges that face accelerometers as a measurement tool of daily physical activities. Reliability and cut-points for defining intensity levels are top challenges that researchers focused on. In [5], accelerometers have shown high technical reliability with repeated 4-7 day periods. The four repeated 4-7 day samples results in 90% reliability for children ordered from least to most active compared to just 71% reliability from a single 4-7 day period. Regarding the cut-points, a cut-point larger than or equal to 3000 counts/min are defined for vigorous activity in the range used to define "moderate-and-vigorous" activity (MVPA), which is larger than or equal to 2000 to larger than or equal to 3600 counts/min.

Also, researchers in [6] investigated the feasibility of using accelerometers to measure the physical activity with young adolescents. The authors argued that although accelerometers provide valid measures of these activities, the feasibility of using accelerometers with large groups of children is unknown [6]. They evaluated feasibility in the Eating and Activity Survey Trial (EAST Project), which is a special purpose study, designed to provide valid tools to evaluate eating and physical activity patterns of middle school children [6]. The results proved the suitability of accelerometers for most of grade 6-8 students and showed that the accelerometers must be worn in proper and regular basis [6].

The researchers in [7] investigated the validity of using uniaxial and triaxial accelerometers to measure 8 'free-play' activities of different intensity, which ranged from light to very vigorous such as hopscotch and basketball. They tested the Computer Science and Applications (CSA) uniaxial and the TriTrac-R3D triaxial accelerometers with 44 children of 9-11 years old along with a heart rate monitor for 5 minutes in each activity.

Tritrac counts were the most significant and this experiment proved the accelerometers efficiency to measure the free play physical activities of children.

A report of physical activity of Canadian children and youth is presented in [8]. It uses the accelerometer results from the year 2007 to 2009 Canadian Health Measure Survey to estimate the level of physical activity for children aged 6-19 years. This report shows several critical findings such as Canadian children spend around 62% of their waking hours in sedentary, which is a dangerous indicator to obese children. Also, boys are more active than girls regardless of age group and the level of physical activities of Canadian children and youth are generally low.

Furthermore, [9] focuses on the obesity issue and shows how accelerometer can be utilized to measure physical activity in children attending an obesity treatment intervention. The researchers asked 28 children aged 7-13 years to wear an Actigraph for 7 days and complete an activity diary. More than 90% of children delivered accelerometer data of 4 days while around half of them delivered accelerometer data of 7 days. Also, 60% of children provided completed diaries. The study showed that accelerometers are acceptable by most of obese children although its usage caused problems for some of them [9].

Regarding the practical implementation of accelerometers, there are several key factors that must be taken into account. Some of these factors are device selection, number of monitor and placement location, distribution and collection, compliance and data interpretation [10]. There are specific concerns related to each factor; for example, cost, reliability, practicality and desired comparability are significant for device selection [10].

III. THE PROPOSED SYSTEM

The proposed system is illustrated in Figure 1. It provides food recommendations, by calculating daily energy expenditure, while being allergies-aware. In this system, an accelerometer as a biofeedback sensor is attached to child's shoes to monitor and collect raw data (x, y and z coordinates) about child current physical activity. Figure 2 shows the accelerometer used in this system. We choose the shoes as a place to attach the accelerometer to enhance the child's comfort and to maintain continuous monitoring. The information is transmitted wirelessly via Bluetooth to a processing unit where the Energy Expenditure Algorithm is implemented.

The energy expenditure algorithm in this system is built based on the algorithm mentioned in [12]. In this algorithm, raw sensory data (x, y, and z) are used to determine user's current physical activity. Then, a pre-defined METS values for each physical activity are used to calculate the calorie consumption through the following equation [12]:

$$Energy\ (kcal) = 1.05 \times METS \times Weight\ (kg) \times Exercise\ time(h) \quad (1)$$

There are standard tables that provide METS values for a wide range of exercises and activities. Table 1 presents some of these values for children's different contexts, which are derived from [13-15]. Consequently, the food recommendation system provides a personalized list of recommended food, which includes several alternatives to satisfy the child's preferences and avoid potential allergies. Finally, the system's findings are presented to the parents via a display device such as smart phone or personal computer.

Figure 2.Simmer Accelerometer circuitry.

TABLE I. METS VALUES FOR PHYSICAL ACTIVITIES

Context	METS Value
Active video games	2.9 ± 0.6 to 5.0 ± 0.8
Non-Active video games	1.3 ± 0.2
Resting/sleeping	1.0 ± 0.2
Sitting	1.1 ± 0.2
Sitting and watching TV	1.3 ± 0.2
Moving and Watching TV	3.3 ± 0.6 to 5.7 ± 0.8
Dancing and Dance Revolution	4.9 ± 0.6 to 8.6 ± 0.8
Standing	1.2 ± 0.2
Walking	6.1 ± 0.6
Jogging	12.9 ± 0.6
Karate	13.1 ± 0.6 to 15.5 ± 0.8
Swimming	5.5 ± 0.6
Tag Games	5.1 ± 0.6
Active video games	2.9 ± 0.6 to 5.0 ± 0.8

IV. IMPLEMENTATION AND EVALUATION

A prototype is implemented to prove-concept the proposed system. The focus of this system is to provide food recommendations by considering child's health conditions and preferences.

The current implementation has adopted the Food Guide Pyramid issued by The USDA, which classifies food into five major food groups: grain, fruit, vegetable, dairy, and meat and bean [16][17]. The daily estimated calories and recommended servings for children aged 4-8 years old are considered. The number of needed calories for this age group is 1200 Kcal for female and 1400 Kcal for male in sedentary situation [18]. If a child has a moderate level of physical activities, then we can add up to 200 Kcal to his food portions, which makes the number of recommended calories 1400Kcal for female and 1600 Kcal for male [18]. However, if the child is highly active, 200Kcal to 400 Kcal can be added [18].

The system is demonstrated using a walkthrough example: Consider a child named Ali who suffers from fish allergy and reduction in vitamins A, B6 and D. He is grade 1 student at school (6 years old), weights 21 Kg and moderately physically active boy. Table 2 shows the calculated calories for the various activities measured using acceleration data and the time of exercising using equation (1). The proposed system provides Ali's parents with lists of daily recommended food from the five food groups with the calories number of each food group while taking into account Ali's health conditions (fish allergy and reduction in vitamins A, B6 and D) in addition to his preferences in each food group.

TABLE II. ALI'S PHYSICAL ACTIVITIES IN A NORMAL SCHOOL DAY WITH THE ESTIMATED NUMBER OF CONSUMED CALORIES.

Physical Activity	Duration (Hours)	Consumed Calories
In class activities: sitting, moving, participating, talking, eating, etc.	5.5	363.8
Walking	0.25	33.6
Jogging	0.25	71.1
Free play (Tag games)	0.25	28.1
Sitting and reading	0.25	14.3
Total	6.5	510.9 Kcal

The results of food recommendations are shown in Table 3. The table (Table 3) shows suggested food for school day to cover the number of calories that Ali's consumed daily (510Kcal). In fact, it represents around one third of the recommended number of calories for him daily (1500 Kcal) based on his age, gender and physical activity level. Note that carrots and spinach are rich sources of vitamin A, chickpeas and potatoes are rich sources of vitamin B6 and orange juice is a natural source of vitamin D [19]. Also, chicken and eggs are natural sources of all these three vitamins [19].

V. CONCLUSION

In this paper, we have presented a diet advisory system for children using biofeedback sensory technologies (accelerometer) to detect activities and measure their duration. We have shown the system architecture and explained the algorithm we used for energy expenditure as

TABLE III. TWO LISTS OF SCHOOL DAY RECOMMENDED FOOD FOR ALI BASED ON HIS PREFERENCES AND HEALTH CONDITIONS

Food Group (500Kcal/school-day)	Number of serving	Ali's Preferences	Recommended Food (List 1)	Recommended Food (List 2)
Grain (213 Kcal)	2	Pasta, cereals	1/2 cup of cooked pasta 1 bread slice	1/2 cup of ready-to-eat cereals 1/2 cup of cooked pasta
Vegetables (106 Kcal)	1	Carrots, potatoes	1/2 cup of cooked potato	1/2 cup of raw carrots
Fruits (71 Kcal)	1	Mango, apple, orange	1 apple	1 banana
Milk and Dairy Products (71 Kcal)	1	Chocolate milk, cheese stick	1 cheese stick	1 yogurt bottle
Meat and Bean (71 Kcal)	1	Chicken and Chickpeas	1 egg (boiled or cooked)	1/3 cup of chopped and cooked chicken

well as METS values that are specific to children's various activities (Table 1).

A walk-through example is used to demonstrate the effectiveness of the proposed system to provide healthy food recommendations while taking into considerations the children preferences and health records. Our future work includes exploring other types of recommendations (such as for activities and/or clothing) to promote well-being as well as providing complex food recommendations such as specific dishes by considering the same criteria.

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