Detection and Assessment of Behaviours Associated with the Risk of Obesity in Adolescents

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Abstract. Obesity in younger age groups has been recognized as an alarming key predictor for obesity in adulthood. PEGASO aims to develop a solution involving wearable devices and an mHealth based application running on a smartphone and cloud computing infrastructure, with the capability of gradually changing harmful behaviours and encouraging healthy habits in adolescents. We present an assessment strategy in the short and long term to evaluate behaviours associated with the risk of adolescent obesity from scientifically informed indicators.

Keywords: Obesity · Physical activity · Adolescents · mHealth · Wearable · Behaviour recognition

1 Introduction

Obesity in younger age groups has been recognized as an alarming key predictor for obesity in adulthood [13], beside having a serious negative impact on health and social and psychological well-being also during juvenile age. Appropriate levels of physical activity, and adequate nutrition are recognised as having a key role for obesity prevention, furthermore the adoption of healthy habits in eating, and an active lifestyle determine in children and adolescents a reduction of the risk for developing obesity [9,12,14]. Therefore, the leveraging of behaviour change towards positive lifestyles is a primary component of a preventive approach.

The rapidly growing availability of wearable devices, and mobile phones connected to the internet has allowed for research into newer innovative and scalable solutions for personalised interventions for the prevention of obesity [5], which may overcome the limitations deriving from face-to-face interventions (small effects and limited reach) or disseminated through mass media approaches (generic content and poor personal relevance of feed-backs) [11]. However, a prerequisite for widespread efficacy of health behaviour change interventions is the

K. Giokas et al. (Eds.): eHealth 2016, LNICST 181, pp. 253–258, 2017.
DOI: 10.1007/978-3-319-49655-9_33

exploitation of a behaviour detection and assessment approach based on objectively measured parameters and scientifically evidenced criteria for evaluation [2].

The *Personalised Guidance Services for Optimising lifestyle management in teenagers through awareness, motivation and engagement* system (PEGASO) [3] is built upon mobile health (mHealth) and cloud computing technologies, which are articulated to analyse adolescents' behaviours and trigger personalized actuations that foster behaviour change. For physical activity and resting attitudes (sleep included) which are the focus of the present paper, the analysis of user's behaviour detected through objectively measured variables (with smartphone sensors and wearable devices) relies upon evidence-based criteria and takes advantage of cloud solutions to perform a two-stage processing of the user-generated data at distinct interval durations: into daily aggregated summaries (24 h timespan), and uploaded into a cloud based data repository for further processing. This analysis will provide the user with different levels of feedback and interaction. Data collected in the smartphone is continuously analysed to provide almost real-time response to detected events such as behavioural abnormalities. In the cloud, the data is analysed over a longer timespan (1 month) so that the system can identify the user's behavioural trends and evaluate her progress on the long term goals set in the platform.

2 Method

A number of behaviours whose correlation to obesity is representative and measurable have been identified by recent biomedical research [7,14]. In PEGASO, the behaviours of interest are referred as targets, so the term ***target behaviour*** defines an absence of a healthy habit that is susceptible to be changed, and represents a threat to the health of the adolescents in a short and long-term period. On the basis of their coherence and relevance with PEGASO requirements (i.e. strength of correlation with obesity onset and measurability through wearables) ten target behaviours were selected. Common to all selected behaviours is the characteristic that they are amenable to positive change. Among the behaviours, six that refer to physical activity, sedentariness and sleep attributes are the focus of this work. Different sources of information throughout PEGASO produce the necessary data to model and quantify the behaviour of the user. The Sensing System, designed and implemented within PEGASO, is composed of a smart bracelet, a smart garment and smartphone embedded sensors. They collect information about human kinetics and cardiovascular activity which, after a post-processing phase, provide data about the time spent doing activities of different intensity (walking, running, biking, swimming, etc.), the number of steps done throughout the day, the distance, the energy expended and other parameters related to sleep. The design of each wearable was completed within the project, and took into account quality control assessments to ensure the reliability of the measured parameter. Furthermore a data fusion algorithm (beyond the scope of this paper) to enhance reliability was implemented when the same parameter (e.g. steps walked) was measured by more than one wearable sensor.

Assessment of Target Behaviours in the Short-Term. Short-term behaviour is defined as the sum of the actions that PEGASO is able to detect during the shortest period of assessment (generally one day), evaluated and converted into a score. Experts in the project used the indications contained in the international guidelines and evidence-based literature to set referenced cut-offs permitting a classification of each behaviour and building a scoring system for the behaviour assessment in the short-term. Table 1 summarises the translation into scores the objectively detected behaviours, which are measured according to the degree to which the user adheres to the recommendations. In the system, 0 indicates the compliance with recommendations (and hence also the lowest risk for obesity) and 2 indicates the worst adherence to recommendations (and hence the highest risk).

Assessment of Target Behaviours in the Long-Term. Long-term behaviour is the sum of short-term behaviour assessments that captures the general trend over a longer period (initially defined as 4 weeks). This allows the system to assess if behaviour change has indeed occurred in the user, and is not just a temporary fluctuation of their habit. The long-term score for target behaviours is calculated from the daily (short-term) scores calculated over the long-term period. As in the short-term scores, a score of 0 indicates the lowest risk level and the presence of the healthy habit, conversely a score of 2 indicates the highest risk level and the absence of the healthy habit. Figure 1 shows the relationship

Table 1. Short-term behaviour scoring system

Target behaviour	Cut-offs	Risk score
Exercising [15]	$\geq$ 60 min/day of moderate-vigorous activity	0
	$\geq$ 30 and $<$ 60 min/day	1
	$<$ 30 min/day	2
Walking [6]	$\geq$ 12000 steps/day	0
	$\geq$ 6000 and $<$ 12000 steps/day	1
	$<$ 6000	2
Active transportation [8] to school	Walking, cycling, skateboarding both journeys	0
	Motorised means on one journey	1
	Motorised means both journeys	2
Non-sedentary lifestyle [1]	$\leq$ 45% of total daily activity $<$ 1.5 METS	0
	$>$ 45% and $\leq$ 55%	1
	$>$ 55%	2
Sleeping enough [10]	$\geq$ 8 hrs of sleep per night	0
	$\geq$ 7 hrs and $<$ 8 hrs of sleep per night	1
	$<$ 7 hrs of sleep per night	2
Sleeping well [10]	sleep time is $\geq$ 95% of overall time in bed	0
	sleep time is, $\geq$ 90% and $<$ 95% of overall time in bed	1
	sleep time is $<$ 90% of overall time in bed	2

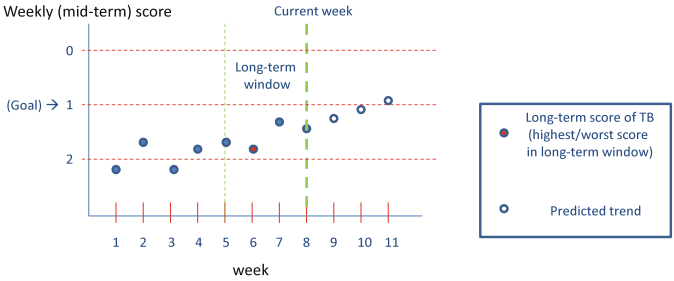

Fig. 1. Long-term (monthly) and mid-term (weekly) assessment of a target behaviour

between long-term and intermediate mid-term weekly score (mean of a week of daily scores). The long-term score is defined as the maximum (or worst) of the weekly scores, thus to increase in this score, the user must sustain the good behaviour over the full period of the long-term window, rather than have variable behaviour (e.g. time spent in sedentary activity some weeks of high performance, and some weeks of low performance).

Use of Behaviour Assessment. The user interacts with PEGASO through a centralised app called the *Companion* [4], which is an advanced interface that assist, and entertains the user providing her with education on healthy habits, and motivating to comply with personalised goals. After an initial assessment period, the Companion uses the long-term scores to help a user select a target behaviour to improve, offering her a choice of the poorer performing ones. The goal of the user would be then to improve in the long-term score by one level before having the choice to select a different behavioural goal. The system module implementing short-term assessment provides instantaneous detection of positive or negative performance prompting the Companion to trigger an appropriate action, for example, giving virtual points and congratulating the user for reaching the step count goal 5 days in a row.

3 Conclusion

This paper has presented a method for assessing behaviours (physical activity and resting attitudes) in the short (daily), medium (weekly) and long term (monthly) based on indicators derived from wearable sensors. We have developed a scientifically informed system of scoring that is associated to the degree of obesity risk each individual target-behaviour conduces. These scores are to be used by components of PEGASO further down the pipeline in order to instigate change in the most relevant behaviours affecting obesity risk. A pilot is scheduled to start in September 2016 involving 400 adolescents. Although nutritional behaviours are also pertinent, and are included in the system, the scope of this paper is limited to behaviours that were inferable from the wearable sensors.

We plan a full study including all aspects of the obesity risk behaviour recognition strategies employed in PEGASO to be published in the near future.

Acknowledgement. The research described in this paper is partly supported by the PEGASO European project (FP7-ICT-2013-10), whose members we would like to thank. The opinions expressed in this paper are those of the authors and are not necessarily those of the project partners or the European Commission.

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