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Electronic health record with computerized decision support tools for the purposes of a pediatric cardiovascular heart disease screening program in Crete

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ABSTRACT

Background and Objective: Early detection of cardiovascular (CV) disease or associated risk factors during childhood is of paramount importance, allowing for early treatment or lifestyle modifications, respectively.

The objective of this study was to describe the development of an electronic health record (EHR), with integrated computerized decision support system (CDSS), specifically designed for supporting the needs of a pilot pediatric CV disease screening program applied on primary school students of a Mediterranean island.

Methods: Evidence-based knowledge, national and international practice guidelines regarding sport preparticipation CV screening of children and young athletes has been used for the design of the designated EHR. A CDSS, capable for providing alerts for further cardiology evaluation need, has been incorporated into the EHR, based on normative anthropometric and electrocardiographic data as well as predefined positive history responses.

Results: We developed a designated EHR with integrated CDSS supporting pediatric CV disease screening, capable for documenting CV-related personal and family history responses, physical evaluation data (weight, height, blood pressure), allowing for entering electrocardiogam (ECG) measurements and for uploading of multimedia files (including ECG images and digital phonocardiogram audio files). The EHR incorporates clinical calculators and referral alerts for the presence (and degree) of adiposity, hypertension, ECG abnormalities and positive history responses indicative of high CV disease risk. In a preliminary EHR validation, performed by entering data from 53 previously available paper-based health records, the EHR was proven to be fully functional.

Conclusions: The pediatric cardiology EHR with CDSS features which we developed might serve as a model for EHR for primary health care purposes, capable to document and early detect CV disease and associated risk factors in pediatric populations.

1. Introduction

Early recognition of CardioVascular (CV) Disease precursors already during childhood is of paramount importance. CV Disease (as atherosclerosis and coronary heart disease) is among the leading causes of morbidity and mortality and related health care costs worldwide [1]. It is associated with well described and potentially modifiable risk factors (as adiposity, hypertension etc.) [2], often present already in childhood [3] and if not appropriately early detected and modified [4] can persist up to adulthood. [5].

Furthermore, early diagnosis during childhood of less common forms of CV Disease such as Congenital Heart Disease (CHD) [6] and Inherited CV Diseases associated with increased risk of sudden cardiac death (SCD) can offer early treatment and reduce associated morbidity and mortality [7].

However, despite the importance of early detection of CV disease and associated risk factors during childhood, most of scientific research, health policies and resources are focusing on adult CV disease. Several adult CV disease risk factors scores have been developed, validated and clinically applied [8], often supported by well validated computer based applications including clinical cal-

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culators [9], and computerized decision support systems (CDSSs) linked to Electronic Health Records [10]. Comparable to this, the study of childhood CV disease and associated risk factor assessment and that of relevant computer-based applications is rather limited [11]. However, few well designed pediatric cohort studies and registries have proved tracking of CV risk factors into adulthood [5] and limited studies validated the performance of massive cardiac screening of school age children, for early diagnosis of CV disease [5,12,13].

In Greece, a mandatory universal health screening of all primary school students, including evaluation by a cardiologist, at 3 year-intervals, had been enforced by state law, for several years (2006 −2014) (National Directive 859 /2005). The policy of universal mandatory health screening of primary school students still remains, although a basic CV evaluation (history and physical evaluation) is now performed by primary health care physicians only (National Directive 4229/2014). Within this setting, our research group has developed a pilot CV screening Program for primary school students (Cretan Pediatric Cardiology Screening - CPCS- program), based on current recommendations for CV screening of young athletes [14–16]. The research study protocol has been approved by the Greek Ministry of Education (No140729/Γ7 13/12/2005) for pilot application in the island of Crete (total population of 621,000), while the study is approved and supported by the local health authorities (7th Health Region Crete). Children attending the 3rd primary school class (8yrs old), are eligible for participation in the screening program, following written informed consent of their parents. The screening protocol includes history documentation, physical evaluation, 12-lead electrocardiogram (ECG) and digital phonocardiogram (PCG) recording. While our CV disease related history documentation sheet (questionnaire) has been already incorporated into the national health clearance documentation form for school children [16], an EHR for supporting the institutional or national cardiac screening of school children is currently not available. The lack of an EHR supporting school health screening can be viewed within the context of a more general need for establishing integrated primary health care, supported by EHR applications [17,18].

The aim of this study is to present the development, including requirement analysis, design and preliminary implementation of a designated EHR with incorporated CDSS for supporting pediatric CV disease screening. We anticipate that this tool will support national pediatric CV disease screening among school age children, and it could serve as a model for further research and computer based applications in this very important but still underrepresented scientific field.

2. Methods

2.1. Requirement analysis

The first and essential step prior to the design of the EHR was the documentation of the requested requirements that the system should address. These were specified by the priorities and design of the pre-existing CPCS program, along with a need for careful selection of data types that would trigger automated system alerts (CDSS) indicating a potential increased CV risk of corresponding children (Decision Support Features).

2.1.1. Recording personal and family history data

The available (in paper format) demographic, personal and family history questionnaire already used for the purposes of the CPCS program served as basis for the development of relevant data entries of the EHR. Evidence-based knowledge has been used for the development of the paper based questionnaire and of the resulting EHR as well. The questionnaire and corresponding EHR file data entries corresponded to necessary documentation fields based on European [14], American [15] Cardiology and Hellenic Pediatric Society [16] Practice Guidelines as well as to mandatory documentation fields based of national recommendations regarding preparticipation sport clearance procedures for school children (National Directive 4229/2014); in the latter two documents our research group had significant direct or indirect contribution. Personal and family history data entries (binomial data: response yes/no), associated with increased probability of CV disease presence (including personal history of precordial pain, reduced exercise capacity, syncope, palpitations, or family history of sudden cardiac death at a young age) were selected as data types capable of triggering a CDSS alert, identifying the selected patient record as being high risk for CV disease [14–16, 19]. In addition to binomial response documentation, the EHR supported features of free text entry by primary health care physician, further clarifying positive responses and the probability of cardiac origin of the reported symptoms.

2.1.2. Physical evaluation data

Physical evaluation data, including body weight, height and blood pressure were further required data entries, based on national guidelines (National Directive 4229/2014). These numerical data should be automatically compared with established normative age and sex specific values [20,21] prompting the system to provide clinical alerts for the presence of borderline or established hypertension and adiposity, already during data entry.

Further mandatory physical evaluation-based data entries (binomial variables: yes/no) such as the presence of femoral artery pulses and a detailed description of cardiac auscultation findings (presence of innocent, abnormal murmur, extra abnormal sounds) were included, in accordance with current guidelines [14–16]. Two discrete cardiac auscultation data entries were considered, allowing for documentation of both real time cardiac auscultatory findings as well as off-line evaluation of stored digital phonocardiograms by an expert (telediagnosis) [22]. Therefore, the EHR should also support uploading of multimedia (sound) files.

2.1.3. Incorporating ECG

The inclusion of ECG in athlete preparticipation screening is controversially discussed [19], with European [14] and USA [15,23,24] practice guidelines being in favor or against universal ECG screening, respectively. Of note, these guidelines apply only for adults and adolescents (> 12 yr-old) participating in high intensity competitive sports; no guidelines are available regarding ECG screening of younger athletes or children participating in low intensity recreational sports, including school sport activities [19]. We considered though that including ECG screening and relevant data in the EHR, in accordance with our previous research methodology, would provide valuable additional information, especially when screening children at risk of arrhythmia-related sudden cardiac death [25]. The inclusion of ECG represented itself a further challenge for the development of the designated EHR, given the need of manual entry of a considerable number of ECG related data, along with the need for incorporating a medical calculator providing validated interpretation output, based on comparisons with age specific normative ECG data [24,26]. ECG data entry required input of amplitude and duration values of ECG waves (p, QRS, T) in several recording leads (I,II,III,AVF,AVR,AVL,V1,V2,V5,V6), as well as input of heart rate, and interval duration values (PR, QT, QTc), corresponding to a total of 27 numerical data entries). The system should calculate amplitude ratios as well as QTc interval based on simple mathematic formulas [27].