Clinical Decision Support Systems for Primary Care: The Identification of Promising Application areas and an Initial Design of a CDSS for lower back pain

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Summary
Decision support technology has the potential to change the way professionals treat patients for the better. We questioned thirty-three healthcare professionals on their view about the usage of eHealth technology within their daily practice, and areas in which decision support can play a role, to lower healthcare professionals’ workload. Qualitative analysis resulted in an overview of desired eHealth functionalities and promising areas for decision support technology within primary care. Based on these results, we discuss future work in which we will focus on the development, and evaluation of a clinical decision support system (CDSS) for advising patients with physical complaints on whether they should see a healthcare professional or can perform self-care. Next, the CDSS should advise healthcare professionals in selecting relevant training exercises for a specific patient. In first instance, this CDSS is focused on diagnostic triaging and selection of training exercises for patients with nonspecific lower back pain.

Keywords
clinical decision support system (CDSS), eHealth, lower back pain (LBP), primary care.

1. Introduction

In the last decades, the focus of healthcare has shifted from providing intramural and curative care, towards offering extramural care, self-care, and prevention. This shift of healthcare delivery from secondary towards a primary care settings is the result of the World Health Organisation Alma-Ata Declaration [1]. This states that the need for care has to be centred within the primary care setting [2]. As a consequence, the role of primary care professionals (such as general practitioners, nurse practitioners and physical therapists) has changed: They have to deal with a wider range of chronic conditions and an increasing number of patients.

Simultaneously, we are witnessing the rise of eHealth technology. eHealth can be defined as “Health services and information delivered or enhanced through the Internet and related technologies” [3]. Primary care professionals may use eHealth technology to cope with their increasing workload. eHealth technology can, for example, support care professionals in the care of patients with a chronic condition. Remote monitoring in combination with alerting for action when needed can help to reduce the number of standard consults that are normally scheduled to monitor a patient’s condition. Another, more generic, example is that eHealth technology can facilitate video consults or e-consults with patients. Finally, eHealth technology can support patients in their independence and self-management [4], for example by showing them relevant exercises for the day or giving recommendations on how to stop smoking.

Next to the support of daily care, eHealth technology can also be used to support primary care professionals in expanding their expertise. This is becoming a prerequisite now that a great amount of care is moving from a specialized, secondary setting to primary care. Online information sources with evidence-based medical information and clinical decision support systems (CDSSs) can be very valuable here [5].

In this paper, we describe a study that sought to identify application areas within primary care in which CDSSs may enlighten the workload as seen from the viewpoint of healthcare professionals. Literature shows that a close cooperation with the intended end-users is an important step in the design and development of fit-for-purpose-technologies [6]. It is important to understand the end-users opinions, perspectives and work processes, as also shown by a study of general practitioners’ perspectives on electronic medical records systems [7], to improve user adoption of the new technology, and to ensure that the system functionalities will fit into the working processes of the end-users. This certainly also applies to the development of CDSSs.

To find the intended CDSS application areas, we performed in-depth semi-structured interviews with 33 key players in primary care, including general practitioners, nurse practitioners, and physical therapists. From the wishes the interviewees voiced on eHealth functionalities, we deduced the most promising application areas for a CDSS.

2. Related Work

Since the 1960's CDSSs have been developed to support the clinical decision process of healthcare professionals. Musen et al [8] define a CDSS as “any computer program designed to help healthcare professionals to make clinical decisions”. From this perspective, key decision support functions are information management, managing clinical complexity and details by alerting, cost control, and decision support by providing patient-specific recommendations [8,9]. Providing patient-specific recommendations covers the assistance in the determination of a diagnosis, providing advice on therapy, or both diagnostic assistance and therapy advice.

Famous examples of early CDSSs on providing patient-specific recommendations are INTERNIST-1 [10], MYCIN [11], and ONCOCIN [12]. These systems were experimental and intended for use by internists and oncologists. Later, the development of CDSSs has evolved to CDSSs to be used in daily care [13], such as the paediatric clinical decision support system ISABEL [14]. Over time, CDSSs have been shown to improve both patient outcomes and cost of care by prompting, reminding and cautioning clinicians whether or not to do certain things under specific clinical circumstances [15]. Nowadays, CDSSs are also used in daily primary care. In the Netherlands, 89 percent of the general practitioners have some form of clinical decision support on their systems [16]. CDSSs in primary care are mainly used for prevention and screening, drug dosing, medical management of acute diagnoses and chronic disease management [16,17], through the usage of alerts and computerized protocols.

The possibilities of CDSSs will improve when all necessary information is available at the right place at the right time for a specific task. However, at this moment information in primary care is mainly available as data stored in isolated IT systems. Therefore, interoperability among these systems is a must. Interoperability is defined as the ability for two, or more, systems or components to exchange information and to use the information that has been exchanged [20]. Interoperable systems in primary care further enlarge the possibilities for new application areas for CDSSs. Therefore, several large projects have recently started with the aim of achieving interoperability among Healthcare Information Systems, such as ANTILOPE [18] or eLabEL [19].

3. Methods

We held in-depth, semi-structured interviews with professionals working in primary care to identify promising applications for eHealth that may enlighten the workload as seen from the viewpoint of these healthcare professionals. Before each interview, an interviewee received a link to an online survey. This survey contained questions about demographics, self-esteem digital skills, use of technology within their primary care center, their understanding of the scope and value of eHealth
technology, and their current experiences with, and future expectations of, eHealth technologies, including CDSSs.

During the interviews, the following subjects were addressed:

- A typical day at work;
- Characteristics of the patient population, such as percentages of typical chronic illnesses, social economic status, educational level;
- Describing the process of a specific task that appeared to be suitable for eHealth or CDSS support;
- Positive and negative work-related experiences with IT.
- Future expectations of eHealth at their workplace.

All interviews were audio-recorded, transcribed, and coded and analyzed in Atlas.ti. Next, thematic analysis was applied, using the guidelines by Braun and Clarke [21]. A first coding scheme was created based on the interview scheme. During this thematic analysis, new codes could be derived from the data, in which case they were added to the code scheme, and all previous codes were reconsidered.

4. Results

4.1 Interviewee Demographics

Thirty-three healthcare professionals, working in primary care, participated. They worked in seven different primary care centers spread around the Netherlands. The group of respondents included nine general practitioners, eight nurse practitioners, nine physiotherapists, and one district nurse. The other six participants were doctor's assistants (five) and one pharmacy assistant that support these healthcare professionals during their work processes.

4.2 Promising CDSS Areas as identified by the Interviewees

The interviews led to nine application areas for CDSSs in primary care, which are shown in Figure 1.

![Figure 1. Identified CDSS application areas brought forth by general practitioners (GP), nurse practitioners (NP), physiotherapists (PT), doctor's assistants (DA), and other professions (Other).](image)

The identified CDSS application areas can be related to different levels of patient care: general patient care and care for patients with a chronic condition. General patient care comprises visits to the primary care center with acute problems, such as a sprained ankle or a persistent cough. Patients with a chronic condition are patients that are seen regularly by a nurse practitioner (e.g., every three months) and once a year, or in the case of an exacerbation, by a general practitioner. Therefore, it is
not surprising that ‘patient monitoring’ in combination with an ‘alert system’ is mainly preferred by nurse practitioners. One interviewee mentioned this as follows:

“If the possibility of automatic patient monitoring exists, it would be most ideal when a system also provides an alert as “this lady has these monitored blood sugars and this average is too high.” Furthermore, it would be nice to have a list of patients within our own information system that works with colors, with on top the patients with red and orange states. Then you know at once which patients need the most attention.”

Another application area in which a CDSS can play a critical role is ‘Patient education’. Patients can be provided with relevant information, for example, to perform self-care. A well-informed patient is in a better position to perform self-management when confronted with health problems [22]. In the Netherlands, general practitioners, nurse practitioners, and doctor’s assistants often encourage patients in self-care by referring to http://www.thuisarts.nl, a website with reliable and independent information about health and disease based on clinical protocols. This website was developed, and is managed, by The Dutch College of General Practitioners (NHG). The NHG is the scientific society of Dutch general practitioners with the mission to improve and to support evidence-based general practice. An English equivalent of this site is http://www.webmd.com/. A CDSS that automatically shows webpages containing relevant information, based on already known health data of a patient will aid patients’ online information-seeking behaviour in a more intelligent and safe manner.

The functionalities ‘patient coaching’, and ‘patient training’ are often mixed. The term ‘coaching’ refers to the activity that the patient is coached in, like smoking cessation or improving one’s lifestyle. The term ‘training’ refers to online training programs that provide and guide patients through a scheme of physical or mental exercises by means of movies, pictures, and text. These training exercises are prescribed by the healthcare professional and patients should perform these exercises at home to improve their physical or mental condition. However, in practice, these schemes are often not adhered to by patients [4]. During the interviews, ‘patient training’ was mainly mentioned in the context of care of patients with musculoskeletal/sports problems within primary care. For example, the following comment was given by a general practitioner during an interview:

“I now have a print-out with pictures of some exercises for low back pain and neck pain, sore shoulder, knee problems. These are the most common complaints. People are happy to be guided in this. It would be nice to have our own physical therapist, or a website of physical therapy, that supports the selection of proper training exercises for a specific patient. A website with physical therapy exercises that people can already perform or can be searched. And yes, thuisarts.nl also provides information on back pain and related exercises, but there are no pictures, only text. That is not enough support for people”.

A CDSS on training advice can support healthcare professionals in selecting suitable exercises for a patient. These exercises help the patient with a given complaint and can be executed at home in a safe manner. Such a personalized advice can improve patients’ adherence to such schemes, which is currently low to very low. Next, a website with exercise movies is better equipped in explaining how patients should perform their exercises correctly and safely.

The application areas ‘triage’ and ‘the preselection of the relevant health care professional’ are related to actions prior to the visit of a patient to a primary care center. In this context we can also take into account the application area ‘questionnaires as pre-consult’. During the interviews, all physiotherapists indicated that they ask patients to fill in a questionnaire about their complaints prior to the first visit as pre-consult. During the consult, information gathered through these questionnaires helps the physiotherapist in setting the right diagnosis. A CDSS that helps a patient through a triage process, and that also involves the relevant pre-consult questionnaires during this process, will save time during the first consult. Next, the outcome of the triage process can also give advice whether to perform self-care, as described in the context of ‘patient education’, or give advice which healthcare professional in the primary care center can best be consulted based on his or her expertise.

Figure 1, finally, also lists ‘prescription refills’ as a CDSS application area. CDSSs on drug dosing already have quite a tradition and are described in detail in the literature [17].
5. Discussion

By means of an interview study, we identified a set of application areas in which Clinical Decision Support Systems (CDSSs) can aid healthcare professionals within primary care. In literature, CDSS applications described most are focused on diagnostic assistance, managing clinical complexity and details by alerting, and providing advice on therapy [8,10-12,15]. However, the application areas ‘triage’ and ‘patient training’ have little or no existence in primary care at this moment.

With ‘triage’ we see promising possibilities for web-based triaging by patients themselves. In fact, this may also be a supplement on diagnostic assistance. An online triage CDSS can give a patient advice whether to see a healthcare professional, or to perform self-care, in an intelligent and safe manner. This advice is then based on answers given by the patient on triage questions. Subsequently, information gathered during the triage process can be used by the healthcare professional to have a more efficient consultation. Avoiding unnecessary visits to the centre, by providing the patient with self-care information when applicable, will reduce health care costs and unnecessary burden for the patient. Next to ‘triage’, we also see ‘patient training’ as a promising CDSS application area in primary care in the context of patient rehabilitation. A CDSS that informs patient training can support health care professionals in the selection of the exercises that match the situation of an individual patient best.

A CDSS can be a stand-alone system. However, decision support by a CDSS can be made more efficient and easy to use when it becomes integrated with current available information systems. In other words, when different systems become interoperable and can exchange data, computerized decision support becomes more powerful. For example, when a CDSS becomes interoperable with information systems that contain a patients’ electronic health record (EHR), EHR information can then be used as additional information to improve the CDSS advice. Despite the fact that interoperability in healthcare is still a challenge [19,23], it is important to take into account the future possibilities of interoperability in health care when developing a new CDSS application. Also a close cooperation with the intended end-users has still be important [6,7] in selecting what systems have to be connected to exchange data in relation to working processes.

5.1. Future Work

Driven by the findings of our interview study, we will develop a CDSS that consists of a triage part and a training-recommender-and-rehabilitation-part for matching patients to a suitable healthcare professional or self-care advice, and for selecting a personalized rehabilitation scheme for the domain of musculoskeletal/sports problems. Within primary care, such problems are commonly dealt with by a general practitioner or a physiotherapist. And in the Netherlands patients can see a physiotherapist for a complaint without a referral from their general practitioner (so-called self-referral) [24]. This certainly has improved the choice of care for the patient, but this also requires from a patient that he or she exactly knows when it is best to visit a general practitioner, to visit physiotherapist, or to perform self-care. An online web-based triaging CDSS will be helpful for patients in making this decision.

Next to triage, the CDSS will, subsequently, support healthcare professionals in the selection of the rehabilitation training exercises that are most suitable for a specific patient, and support patients in the individual rehabilitation process at home. We expect that personalized treatment schemes, and a system that encourages patients to perform exercises at home, will improve patient adherence.

The domain of musculoskeletal/sports problems is still a large domain. Therefore, we initially will focus the CDSS on the domain of lower back pain (LBP). On this topic, evidence-based clinical guidelines regarding diagnosis and treatment exist [25-27]. These guidelines will form a solid starting point in the design of the triage part of the CDSS. Another reason for developing a CDSS for lower back pain is because literature on CDSS for diagnostic triaging on LBP is sparingly [28,29], although more than 80 percent of the people will have significant LBP at some point in their life. About 20 percent of the LBP patients develop a chronic problem, which is debilitating for the patient and costly for society [31]. Therefore we want to avoid the development of acute LBP to chronic LBP as much as possible, a process that starts in primary care by identifying those acute LBP patients that are susceptible to
develop chronic LBP. Furthermore, the guidelines on LBP also indicate that most patients with acute problems and a normal course of LBP can be helped by information to perform self-care at home by keeping active. This can also be guided by the CDSS rehabilitation part. From this all, it can be concluded that using LBP as a case in the development of our CDSS has a high relevance for improving healthcare.

The next sections describe both the CDSS triage part and a training-recommender-and-rehabilitation-part, that are also subsequently shown in Figure 2 and 3.

5.1.1. The CDSS triage part

![Diagram of CDSS triage part](image)

**Figure 2** Visualization of the CDSS triage-part. In this figure, the HIS is the medical information system of the general practitioner, and the FIS is the medical information system of the physiotherapist.
The CDSS triage part (Figure 2) will guide patients through a decision process that has one of the following three outcomes:

1. To see a general practitioner, or
2. To see a physiotherapist, or
3. To perform self-care.

The primary end-users for the CDSS triage part will therefore be patients. Patients use the CDSS triage part before the first visit on acute LBP. In order to achieve one of the three possible outcomes, the CDSS triage part will use

- Answers on triage questions,
- Information about a patient from the EHR in the Medical Information System (MIS) when the CDSS and the MIS are interoperable, and
- General knowledge on specific and non-specific LBP.

When the patient is visiting a healthcare professional, this healthcare professional has access to the answers of the patient, given during the triage process. This information will enable a more in-depth, and efficient, consult with the patient, because basic questions on the problem have already been posed by the CDSS.

The usage of this CDSS part should lead to a decreasing number of visits of patients with LBP in primary care, because patients that can handle their LBP with self-care will be filtered beforehand. However, patients with serious underlying conditions or suffering from psychosocial factors must be detected and referred to the most suitable healthcare professional for further examination.

5.1.2. The CDSS training-recommender-and-rehabilitation-part

Based on the diagnosis made by the healthcare professional, the CDSS training-recommendation-part (Figure 3) will provide the healthcare professional with a recommendation on a personalized training scheme with exercises for a given patient. Therefore the primary end-user of this CDSS part is the healthcare professional.

Normally, general knowledge on LBP is used to relate to appropriate exercises as specified in guidelines on LBP. Worldwide, general practitioners and physiotherapists use guidelines in the clinical evaluation and classification, and management of LBP. However, literature shows that guideline adherence by professionals is not always the case due to various barriers these professionals met when they try to incorporate these clinical guidelines into their care practice [30]. The adherence varies between general practitioners and between guideline recommendations [32]. Therefore, this CDSS might also help to improve guideline adherence by health care professionals.

The given recommendation of the CDSS training-recommendation-part is based on

- Information retrieved by the CDSS triage part (when available), and
- Information provided by the healthcare professional which is retrieved during the consult with the patient, and
- Already available information on this patient as stored in the EHR in the medical information system (MIS) when the CDSS and the MIS are interoperable, and
- General knowledge on specific and non-specific LBP.

In this list of information sources, the input of information retrieved by the CDSS triage part is optional. When this information is available, the treatment advice can be more precise, but it should also be possible to use the CDSS training-recommendation-part as a single component, independent from the CDSS triage-part. On the other hand, when the CDSS triage part advises a patient in self-care, the
CDSS training-recommendation-part can be used to provide the patient the most-suited exercises. Although the CDSS provides an advice for a treatment scheme, the healthcare professional should always have the possibility to adapt a recommended scheme of exercises. This is because, ultimately, it is the healthcare professional that stays responsible for a patient’s treatment. Furthermore, there can always be extern reasons, not known by the CDSS, why an advised treatment scheme has to be adapted for a patient by the healthcare professional. Finally, the achieved training scheme of exercises can serve as input for the support of individual rehabilitation of patients at home by an external training and exercise coaching program. In Figure 3 this system is called RRD COCO, an already available system [33]. With this extension of the CDSS, secondary end-users of this CDSS part will be patients who perform exercises at home.

Figure 3. Visualization of the CDSS training-recommender-and-rehabilitation-part. In this figure, the HIS is the medical information system of the general practitioner, the FIS is the medical information system of the physiotherapist, and RRD COCO webservice the external training and exercise coaching program.
5.2. Development and evaluation of the CDSS

The development of a CDSS exists of various steps. Prior to the actual development of the CDSS the following parts have to be designed: 1. A knowledge base, 2. An inference engine, and 3. A communication mechanism that defines the human-machine-interaction.

An ontology forms the basis of the design of the knowledge base and the inference engine. An ontology is “a description of the concepts and relationships that can exist for an agent or a community of agents” [34] and defines the vocabulary for a domain and the relations among concepts. During the definition the ontology, we will investigate whether we can make use of available terminology systems to define the ontology. A very suitable candidate for a terminology system will be SNOMED CT as it facilitates semantic interoperability with other Medical Information Systems [35]. The storage and access of knowledge will be determined by the knowledge base, which will be built upon the ontology. We will use Protégé [36] to create the ontology for our application.

A challenge in our future research is that we have to find the optimal knowledge representation format for our CDSS. Knowledge representation formats are, for example, logic-based knowledge representation, procedural knowledge representation, networks (such as Bayesian belief networks), decisions trees, and artificial neural networks. As healthcare is not a static domain and also utilizes casual and temporal knowledge, we will also have to look at formats for representing these kinds of knowledge, taking into account that all of this knowledge will change over time. The latter is known as the “frame of reference” problem [37].

We will start the design of the CDSS by defining an ontology. In this, it is important to know the domain and the end-users. Furthermore, a key issue in building an ontology is term selection. Therefore, we will interview general practitioners and physiotherapists on their approach to the treatment of LBP patients, and the use of guidelines in the clinical evaluation and classification, and management of LBP. Themes in these interviews will include:

- Demographics of the interviewee;
- Expertise of the interviewee on LBP (e.g., how often this health care professional sees a LBP patient, how knowledge on LBP is kept up to date);
- Steps in the clinical evaluation and classification, and management of LBP, by asking out the healthcare professional on specific patient cases;
- Definitions on LBP concepts;
- Future expectations of a CDSS that supports healthcare professionals and patients in the evaluation and classification, and management of LBP.

We will use case descriptions of fictitious patients as a means to identify steps in the clinical evaluation and classification, and management of LBP. These cases will be based on clinical guidelines on LBP [25]. The patients’ cases will differ in a way that the steps in analyzing these cases lead to different outcomes on the clinical evaluation and classification, and management of LBP. This differentiation is made by using so-called red flags and yellow flags in these cases. Red flags indicate LBP problems that are caused by serious underlying conditions [26] and yellow flags indicate psychosocial factors are associated with a poor prognosis of LBP [25,38]. Next, the cases include differences for demographics, social-economic status, and medical history to elicit tacit knowledge, because we also want to find out if healthcare professionals make decisions not documented in the guidelines, but which are based on personal experience [39].

Based on these interviews, we will build an ontology. We first will design, develop and implement the CDSS triage part in the near future. The design and development of the CDSS training-recommender-and-rehabilitation-part is planned at a later stage, namely at the moment when exactly is known what kind of information is retrieved by the CDSS triage that can serve as input for the second part of the CDSS. Therefore, this first ontology will define the concepts and inference steps important in the triage process of acute lower back pain.

To evaluate this first ontology, we will present the result to the interviewed healthcare professionals. Based on new patient cases on LBP, these professionals will test this ontology on completeness and consistency. When needed, the ontology will be adjusted, and this process is repeated until a constant
ontology has been achieved. Subsequently, the CDSS triage part will be developed, based on this ontology, and then evaluated.

In literature, several systematic reviews can be found on studies that evaluate CDSS on practitioner performance and patient outcomes by means of controlled clinical trials [40]. However, health informatics still lacks well-established instruments and outcome variables to measure efficacy and effectiveness of CDSSs [40,41]. Because no evaluation instruments are available, our intention is to start the evaluation of our CDSS triage part in a Turing-test setting with healthcare professionals as well as patients. In this way, it becomes possible to compare the CDSS outcomes with the current ways of acute LBP classification as performed by healthcare professionals or doctor assistants. Based on the evaluation results, we will decide when we will start the real implementation of the CDSS triage part in daily primary care.

6. Closing Remarks

The interviews we held with thirty-three health care professionals in primary care resulted in a number of promising CDSS application areas. This resulted in a plan for our future work. We will develop a CDSS on the triage, and the recommendation of training exercises, for patients with lower back pain (LBP). The objectives of this CDSS is to provide patients with the advice to see a healthcare professional or to perform self-care. Next, the system will advise healthcare professionals on a personalized treatment scheme with exercises for a patient, and support patients in their rehabilitation process at home (via a web service that includes exercise videos). The objective of such a system is to decrease the number of LBP consults in primary care and to increase treatment adherence. Another important objective is to detect those patients who have problems that are caused by serious underlying conditions, or that are associated with a poor prognosis because of psychosocial factors, in an as early state as possible. This should limit the number of patients developing chronic LBP.

7. Acknowledgements

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