

**UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE
PORTO ALEGRE
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA
REABILITAÇÃO**

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**Sistema de Apoio à Decisão em
Reabilitação Cardíaca Ambulatorial
Supervisionada**

UFCSPA
Universidade Federal de Ciências da Saúde
de Porto Alegre

Porto Alegre

2018

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Sistema de Apoio à Decisão em Reabilitação Cardíaca Ambulatorial Supervisionada

Dissertação submetida ao Programa de Pós-Graduação em Ciências da Reabilitação da Fundação Universidade Federal de Ciências da Saúde de Porto Alegre como requisito para a obtenção do grau de Mestre.

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Flores

Porto Alegre
2018

Catálogo na Publicação

Marcolino, Miriam Allein Zago
Sistema de Apoio à Decisão em Reabilitação Cardíaca
Ambulatorial Supervisionada / Miriam Allein Zago
Marcolino. -- 2018.
109 p. : il., tab. ; 30 cm.

Dissertação (mestrado) -- Universidade Federal de
Ciências da Saúde de Porto Alegre, Programa de
Pós-Graduação em Ciências da Reabilitação, 2018.

Orientador(a): Rodrigo Della Múa Plentz ;
coorientador(a): Cecília Dias Flores.

1. Sistemas de Apoio a Decisões Clínicas. 2.
Reabilitação Cardíaca. 3. Doenças Cardiovasculares. 4.
Aplicações da Informática Médica. 5. Modelos
Probabilísticos. I. Título.

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Porto Alegre

2018

Dedicatória

Dedico este trabalho ao meu esposo, meu melhor amigo e luz de Deus na minha vida Gabriel Prado Marcolino; à minha mãe Madalena Maria Allein Zago e meu pai Aurélio Antônio Zago (*in memorian*), minhas inspirações; e aos meus orientadores Rodrigo Della Méa Plentz e Cecília Dias Flores.

AGRADECIMENTO

Agradeço primeiramente à Deus, que me deu o dom da vida e a liberdade, capacidade e inspiração para perseguir os meus sonhos.

Agradeço imensamente ao meu amado esposo Gabriel Prado Marcolino, por ser meu motivo para sorrir a cada dia, por sempre me dar suporte em tudo que faço, por estar sempre ao meu lado, lutando pelos mesmos objetivos, incluindo este trabalho.

Agradeço também à minha mãe Madalena Maria Allein Zago que sempre me incentivou a buscar o conhecimento, a não desistir no meio do caminho, a ter esperança e confiar em Deus sempre. Ao meu irmão Lucas Allein Zago, com sua esposa Janyelle Lima Zago e seus filhos Levi e Murilo que

Agradeço ainda ao meu pai Aurélio Antônio Zago (*in memorian*), que sempre foi minha inspiração, e, apesar de há muitos anos viver sem sua presença física, a saudade e a memória de seu caráter, inteligência e ternura vivem em mim e me dão motivos para me esforçar sempre mais.

Ao meu orientador Rodrigo Della Méa Plentz, meu agradecimento especial por ter me enxergado e me dado oportunidade de vivenciar intensamente a pesquisa nestes dois anos. A sua paixão pela pesquisa e brilho nos olhos ao falar de inovação me inspiram desde a graduação. Obrigada pelo reconhecimento e carinho de sempre.

Agradeço à minha coorientadora Cecília Dias Flores pela ampla disponibilidade, entusiasmo e interesse por este trabalho e em especial pela ajuda ao Gabriel.

Agradeço a todo o grupo de pesquisa do professor Rodrigo, em especial à Cinara Stein, Jociane Schardong e Melina Hauck que me acompanham desde o trabalho de conclusão de curso do bacharelado e me inspiraram a seguir no caminho da pesquisa. À Isadora Rebolho Sisto, Paula Caballero e Alessandra Tessaro pela amizade que se desenvolveu naturalmente e que foi um grande apoio nesta caminhada.

Agradeço também ao professor Felipe Stigger, pois foram as suas palavras de reconhecimento durante os estágios da graduação, que me deram a segurança para seguir em frente na vida acadêmica. Agradeço a parceria nos

trabalhos que desenvolvemos, mas além disto, agradeço por me tratar sen como igual.

Agradeço também ao Rodrigo Ribeiro, pelo reconhecimento das minhas capacidades e pelo investimento no meu aprendizado e crescimento profissional na pesquisa.

Enfim, agradeço à família Prado Marcolino, por me acolher e acompanhar o nosso esforço nestes dois anos, e à família Castro de Andrade, pois nada do que conquistei desde que vim para Porto Alegre seria possível sem o suporte, carinho e amor que me dão desde 2010.

“Alguns homens veem as coisas como são, e dizem ‘Por quê?’ Eu sonho com as coisas que nunca foram e digo ‘Por que não?’”

(Geroge Bernard Shaw)

RESUMO

Introdução: Sistemas de apoio à decisão (SAD) são ferramentas computacionais que visam auxiliar os indivíduos na tomada de decisão, apresentando boa aplicação para a prática clínica, inclusive para Reabilitação Cardíaca (RC) ambulatorial supervisionada. Entretanto, os SAD em RC existentes não utilizam a incerteza para gerar recomendações, podem ser usados apenas em computadores e nenhum está disponível no Brasil. **Objetivo:** Conceber um SAD para RC ambulatorial supervisionada, baseado em redes probabilísticas. **Métodos:** Este é um estudo metodológico, iniciado pela concepção do *software*, definindo-se a metodologia de desenvolvimento, público-alvo e principais funcionalidades para o sistema. Foram analisados os requisitos funcionais e não funcionais e desenvolvido um diagrama de casos de uso. Foram identificados os componentes da arquitetura do *software* e suas relações, bem como produzido o design da interface do usuário. Para facilitar o uso do SAD por profissionais menos experientes e, possivelmente, como ferramenta educacional, foram desenvolvidas definições para as variáveis dos diagramas de influência (DI) que são a base de conhecimento do SAD. **Resultados:** CardioDSS (“Cardiovascular Rehabilitation Decision Support System”) foi concebido como um SAD orientado a conhecimento, cuja base de conhecimento são dois DI previamente desenvolvidos e validados para apoiar a tomada de decisão de profissionais envolvidos em RC ambulatorial supervisionada. O desenvolvimento do sistema está seguindo a metodologia Scrum, que é baseada em métodos ágeis. Foram identificados 23 requisitos funcionais e 11 requisitos não funcionais para o desenvolvimento do *software* que será disponibilizado para uso em dispositivos móveis com sistema operacional Android. As principais funcionalidades e casos de uso do sistema incluem criação e exclusão de contas de usuários; criação, edição, busca e exclusão de registros de pacientes; disposição para definição de estados para qualquer número de variáveis dos DI; geração de recomendações vinculadas ou não à registros de pacientes, através da propagação dos estados definidos pelos usuários para as variáveis dos DI e permitir a exportação dos resultados. Foram construídas definições para todas as variáveis dos DI, que estarão disponíveis para consulta no momento da definição dos estados das variáveis. A arquitetura do SAD inclui três componentes que interagem entre si: o dispositivo móvel contendo a interface gráfica do usuário, um servidor para autenticação e armazenamento de dados das contas do usuário e um servidor contendo o algoritmo que calcula a propagação dos estados informados nos DI. O design da interface gráfica do usuário foi desenvolvido considerando a facilidade e agilidade no uso e definindo uma identidade visual para o *software*. **Conclusão:** Neste estudo a concepção do CardioDSS, que deve ser o primeiro SAD desenvolvido para dispositivos móveis que considera a incerteza para formulação de recomendações para a tomada de decisão de profissionais em RC ambulatorial supervisionada, foi descrita. O *software* concebido apresenta potencial para tornar-se também uma ferramenta educacional para uso em disciplinas de RC. Este trabalho poderá ser útil para os futuros usuários do *software* no entendimento de sua concepção e desenvolvimento, bem como para servir como uma fonte de informação para o desenvolvimento de outros SAD clínicos para dispositivos móveis.

Palavras-chave: Doenças Cardiovasculares; Reabilitação Cardíaca; Modelos Probabilísticos; *Software*; Aplicações da Informática Médica, Sistemas de Apoio a Decisões Clínicas.

ABSTRACT

Introduction: Decision support systems (DSS) are computational tools developed to assist individuals in the decision-making process, presenting good application to clinical practice, including supervised outpatient Cardiac Rehabilitation (CR). However, existing DSS in CR do not use uncertainty to generate recommendations, they can only be used in computers and none are available in Brazil. **Objective:** To conceive a DSS for supervised outpatient CR based in probabilistic networks. **Methods:** This is a methodological study, initiating by the software conception, defining the software development methodology, the targeted-users and main functionalities of the system. Were analyzed the functional and non-functional requirements, and developed a use case diagram. Were identified the components and the relations of the software architecture and produced the user interface design. To facilitate the use of the SAD by less experienced professionals in RC and possibly as an educational tool, definitions for all variables of the influence diagrams (ID), that are the knowledge-base of the software, were constructed. **Results:** CardioDSS ("Cardiovascular Rehabilitation Decision Support System") was conceived as a knowledge-driven DSS, which the knowledge-base composed by two ID previously developed and validated to support decision-making process by professionals from the supervised outpatient CR. The development of the system is following the methodology of Scrum, that is based on Agile methods. Were identified 23 functional and 11 non-functional requirements to the software development that will be available for mobile devices with the Android operational system. The main functionalities and use cases of the system include creation and exclusion of users' accounts; creation, edition, search, and exclusion of patients' records; disposal for the definition of states to any number of variables of the influence diagrams and allow exportation of the results. All variables of the influence diagrams were defined and the definition will be available for consultation at the moment of the variables state definition. The software architecture includes three components that interact between them: the mobile device containing the graphical user interface, a server to user account authentication and data storage and a server with the algorithm that calculates the propagation of the states informed in the influence diagrams. The graphical interface design was developed considering the facility and agility to the software use, defining a visual identity for the software. **Conclusion:** In this study the characteristics of CardioDSS, which must be the first DSS developed for mobile devices that consider the uncertainty in the formulation of recommendations, helping in the decision-making process of supervised outpatient CR professionals were described. The conceived software shows potential to become also an educational tool in CR classes. This work can be useful for the future users of the software, to understand the conception and development of the system, as well as be a source of information for the development of further clinical DSS for mobile devices.

Key words: Cardiovascular Diseases; Cardiac Rehabilitation; Uncertainty; Probabilistic Models, Medical Informatics Applications; Decision Support Systems, Clinical.

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LISTA DE ABREVIATURAS E SIGLAS

API	<i>Application Program Interface</i>
CardioDSS	<i>Cardiovascular Rehabilitation Decision Support System</i>
CARDSS	<i>Cardiac Rehabilitation Decision Support System</i>
CENTRAL	<i>Cochrane Central Register of Controlled Trials</i>
CR	Cardiac Rehabilitation
DCV	Doenças Cardiovasculares
DI	Diagramas de Influências
DSS	<i>Decision Support Systems</i>
EENM	Eletroneuroestimulação Neuromuscular
EXPERT	<i>Exercise Prescription in Everyday Practice and Rehabilitative Training</i>
FC	Frequência Cardíaca
FES	<i>Functional Electrical Stimulation</i>
GUI	<i>Graphical User Interface</i>
ID	Influence Diagram
MEDLINE	<i>Medical Literature Analysis and Retrieval System Online</i>
PAD	Pressão Arterial Diastólica
PAS	Pressão Arterial Sistólica
PATHway	<i>Physical Activity Towards Health</i>
PEDro	<i>Physiotherapy Evidence Database</i>
RB	Redes Bayesianas
RC	Reabilitação Cardíaca
SAD	Sistema de Apoio à Decisão
TMI	Treinamento Muscular Inspiratório
UML	<i>Unified Modeling Language</i>

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1 INTRODUÇÃO

As doenças cardiovasculares (DCV) são as principais contribuintes para mortalidade e morbidade global (PRICE et al., 2016). No Brasil, são a principal causa de morte por doenças não transmissíveis (BRANT et al., 2017) e representam cerca de 29% da mortalidade total do país num período de 10 anos (2007 a 2016) (DATASUS, 2018). Entre 1990 e 2015 houve uma redução consistente das taxas de mortalidade por DCV padronizadas por idade (BRANT et al., 2017). Consequentemente, há um crescente número de pessoas que sobrevivem aos eventos agudos e convivem com DCV crônicas, sendo necessárias medidas para melhora da capacidade funcional e qualidade de vida destes indivíduos (ANDERSON et al., 2016). A RC surgiu para garantir aos pacientes portadores de DCV crônica as melhores condições física, mental e social, de forma que pelo próprio esforço eles consigam reconquistar sua posição na comunidade e levar uma vida ativa e produtiva (MORAES et al., 2005).

A RC ambulatorial é um cenário de tomada de decisões complexo que envolve a necessidade de conhecimento especializado a respeito do quadro clínico dos pacientes, fatores de risco e comorbidades que possam impossibilitar o treinamento físico, além da decisão quanto ao volume, intensidade e equipamento a ser utilizado, especialmente para o treinamento aeróbico. Apesar das recomendações à realização do treinamento aeróbico, pouco se refere quanto à escolha entre esteira rolante e cicloergômetro, ficando a decisão geralmente à critério dos profissionais e do serviço (ACHTTIEN et al., 2015; HERDY et al., 2014; MORAES et al., 2005; PIEPOLI et al., 2010).

A prática baseada em evidências, inicialmente definida como medicina baseada em evidências, é o uso “consciente, explícito e judicioso da melhor evidência disponível [integrando expertise clínica individual e os direitos, valores e preferências dos pacientes] ao tomar decisões sobre o cuidado de pacientes individuais” (SACKET et al., 1996). O esforço pela aplicação disseminada da prática baseada em evidências é justificado pelo consenso geral de que a mesma apresenta potencial para aumentar a qualidade e reduzir a variabilidade do cuidado em saúde (JOHNSON; ZHENG; PADMAN, 2014). Entretanto, a produção científica é cada vez mais intensa, existindo uma distância – estimada em 13 a 17 anos – entre a produção de evidências

científicas e sua aplicação na prática clínica (BAUER, 2002). Além disto, treinar um profissional da saúde para entender e memorizar toda a complexidade do cuidado em saúde moderno, mesmo que em sua própria especialidade é um processo longo e penoso (BENNET; HAUSER, 2013), necessitando de estudo continuado.

O reconhecimento de que o cuidado em saúde é variável e possivelmente sub ótimo, incentiva a busca por intervenções que possam prevenir erros e favorecer o uso consistente do melhor conhecimento disponível (ROSHANOV et al., 2013). Os Sistemas de Apoio à Decisão (SAD) – definidos como quaisquer aplicações computacionais que aprimorem as habilidades de um indivíduo ou grupo para a tomada de decisão (POWER; SHARDA; BURSTEIN, 2015) – surgem como uma alternativa à esta realidade, possuindo evidência de melhorar o cuidado em saúde (DELANEY et al., 1999; GOUD et al., 2009; ROSHANOV et al., 2013), reduzir erro diagnóstico (MAIN et al., 2010), aumentar a conformidade com diretrizes clínicas e, conseqüentemente, a saúde dos pacientes (LINDER et al., 2009; SEIDLING et al., 2010).

Uma das formas para o desenvolvimento de SAD é através da construção de redes probabilísticas (Redes Bayesianas (RB) e Diagrama de Influências (DI)). Desde 1980, as redes probabilísticas vêm sendo utilizadas em diferentes áreas da saúde, principalmente para apoio diagnóstico e escolha de conduta terapêutica (VERDUIJN et al., 2007), podendo auxiliar no processo de ensino/aprendizagem em saúde. Uma vez que os SAD não substituem o julgamento do profissional da saúde, resultados positivos do seu uso podem ser sustentados apenas através da melhora da aprendizagem dos profissionais subsidiada pelos SAD (AKÇURA; OZDEMIR, 2014).

Nosso grupo de pesquisa desenvolveu dois DI para apoio à tomada de decisão na reabilitação cardíaca (RC) ambulatorial, sendo estes os primeiros DI desenvolvidos para auxílio a tomada de decisão por fisioterapeutas (KLAHR et al., 2015). Os dois DI foram desenvolvidos a partir de um banco de dados obtido em um centro de RC de referência em Porto Alegre, associado a diretrizes de RC. O primeiro dá suporte à decisão de indicação ou contra-indicação do paciente para a fase ambulatorial supervisionada da reabilitação ou seja, fase II segundo a diretriz nacional brasileira (MORAES et al., 2005), e o segundo dá suporte à decisão de quais as intervenções (treinamento aeróbico, resistido,

eletroestimulação funcional, alongamentos e treinamento da musculatura inspiratória) e qual equipamento é mais indicado para o treinamento aeróbico (esteira rolante ou ciclo-ergômetro) e o tipo de metabolismo energético a ser atingido (aeróbico ou anaeróbico) (KLAHR et al., 2015).

Os DI gerados foram validados por especialistas e foram considerados adequados e representativos do raciocínio dos experts da área, além de serem baseados em evidências. Entretanto, os DI demonstraram-se complexos, com muitas variáveis associadas o que dificulta sua ampla utilização na prática clínica (KLAHR et al., 2015). Desta forma, o desenvolvimento de um SAD é necessário para a disponibilização das recomendações geradas pelos DI de uma forma simples e inteligível no contexto de prática clínica diária.

Uma das características que influenciam o sucesso do uso de SAD, se relaciona à sua capacidade de prestação automática de apoio à tomada de decisão, servindo de suporte no momento e local da tomada de decisão (ROSHANOV et al., 2013). Entretanto, a maioria dos SAD relacionados à cardiologia, seja em controle de fatores de risco para doença cardiovascular, prescrição medicamentosa ou prescrição de exercícios em RC, desenvolvidos até o momento, são disponibilizados apenas para uso em computador (ABIDI et al., 2016; CHATZAKIS et al., 2018; GOUD et al., 2009; HANSEN et al., 2017; MAZZAGLIA et al., 2014; NEUBAUER et al., 2015; ZHU et al., 2017). Uma forma de aproximação do SAD ao momento e local da decisão é sua disponibilização em dispositivos móveis (isto é, celulares, *tablets*) (AJAY et al., 2016; SMARADOTTIR et al., 2018).

Além disto, existem poucos especialistas com alto conhecimento a respeito de RC (CORTES-BERGODERI et al., 2013), alocados geralmente em regiões urbanas (LEAR et al., 2014), o que muitas vezes causa a centralização e falta de difusão deste conhecimento fora destes locais. Considerando que os benefícios dos SAD não são obtidos apenas na sua utilização, mas no aprendizado gerado com seu uso (AKÇURA; OZDEMIR, 2014), é importante que o SAD possa ser utilizado como ferramenta educacional para profissionais e estudantes, facilitando a disseminação do conhecimento a locais distantes dos centros de referências (GOUD et al., 2010; KLAHR et al., 2015).

2 REVISÃO DE LITERATURA – CONTEXTUALIZAÇÃO

2.1 REABILITAÇÃO CARDÍACA

DCV são as doenças não transmissíveis mais prevalentes e são a principal causa de mortalidade (NAGHAVI et al., 2017; WHO, 2011) e incapacidade no mundo (ROTH et al., 2017). RC são programas multifacetados e multidisciplinares que visam otimizar a capacidade física, mental e social de pessoas com DCV (BALADY et al., 2011), de forma que pelo próprio esforço eles consigam reconquistar uma posição normal na comunidade e levar uma vida ativa e produtiva (MORAES et al., 2005). Por este motivo, Carvalho et al. (2006) considera que a RC deva ser denominada Reabilitação Cardiopulmonar e Metabólica (RCPM), uma vez que, segundo os autores, o termo representa o enfoque abrangente do programa, atuando não apenas sobre o condicionamento físico, mas sobre o controle de fatores de risco e estilo de vida.

A importância do exercício físico na RC é indiscutível de acordo com as principais sociedades internacionais de cardiologia, sendo recomendada nas diretrizes e consensos da Sociedade Brasileira de Cardiologia (CARVALHO et al., 2006; MORAES et al., 2005), Sociedade Sul-Americana de Cardiologia (HERDY et al., 2014), *American Heart Association*, *American Association of Cardiovascular and Pulmonary Rehabilitation*, *American College of Cardiology Foundation* (SMITH et al., 2011; THOMAS et al., 2010), *Canadian Cardiovascular Society* (EZEKOWITZ et al., 2017), *European Society of Cardiology*, *European Association of Cardiovascular Prevention and Rehabilitation* (PIEPOLI et al., 2010) além de diversas outras diretrizes produzidas por países europeus e ocidentais individualmente. No entanto, vale lembrar que os pilares da RC são mudanças no estilo de vida, adoção de hábitos alimentares saudáveis, remoção do tabagismo e uso de drogas em geral, além de estratégias para modular o estresse (HERDY et al., 2014), sendo necessária abordagem multidisciplinar, incluindo ações de educação e apoio psicológico (ANDERSON et al., 2016).

A aderência aos programas de RC, como efeito do treinamento físico e cuidado multidisciplinar, promove melhoras na capacidade de exercício e resistência cardiovascular além de redução de fatores de risco cardiovascular como níveis de lipídios e glicose, pressão arterial, inflamação, assim como

melhora do estresse psicossocial e da qualidade de vida (LAVIE et al., 2016; MORAES et al., 2005). Os mecanismos que explicam estes efeitos incluem melhora da função cardiovascular, perfusão e metabolismo muscular, eficiência ventilatória e regulação neuro-humoral (ACHTTIEN et al., 2015; DAVIES et al., 2010). Estes efeitos se refletem em redução da mortalidade cardiovascular em cerca de 26% e da hospitalização de pacientes com doença arterial coronariana em cerca de 18% (ANDERSON et al., 2016). Além disto, a RC ambulatorial supervisionada pode aumentar a expectativa de vida de pacientes com DCV em cerca de 2 e reduzir em 3 vezes o índice de reinternação hospitalar por descompensação (MUELA et al., 2011).

A RC é custo-efetiva para prevenção secundária de pacientes com DCV crônicas (SHIELDS et al., 2018; WONG et al., 2012), sendo imperiosa a implementação de políticas no sistema de saúde público e privado que tornem o método disponível a todos os pacientes elegíveis (CARVALHO et al., 2006). Contudo, apenas cerca de 34% dos pacientes elegíveis para RC são encaminhados para os programas (CORTÊS; ARTHUR, 2006), sendo que cerca de 19% participa de pelo menos uma sessão de RC após a alta hospitalar nos Estados Unidos (SUAYA et al., 2007) e cerca de 41% na Europa (KOTSEVA; WOOD; DE BACQUER, 2018). A disponibilidade de centros de reabilitação no mundo é variável, com maior disponibilidade em países de alta renda (68%) sendo consideravelmente menor em países de média renda (28,2%) e baixa renda (8,3%) (TURK-ADAWI; SARRAFZADEGAN; GRACE, 2015), estima-se que o número de centros de reabilitação nos países também seja pequeno, principalmente nas redes públicas de saúde (CORTES-BERGODERI et al., 2013; GOUD et al., 2010; MUELA et al., 2011; THOMAS et al., 2010).

Existe uma variação na definição das fases da RC entre as sociedades internacionais, mas de maneira geral, é dividida em 3 a 4 fases (HERDY et al., 2014). A fase I, é realizada durante a fase hospitalar, 48 horas após o evento cardiovascular até a alta, com objetivos de prevenir perda de capacidade física, evitar complicações e promover condições ao paciente para iniciar a fase seguinte. Na fase II, foco do presente trabalho, o paciente realiza um programa de exercícios físicos individualizado e supervisionado por fisioterapeuta ou educador físico em conjunto com equipe multidisciplinar, com duração de 3 a 6 meses em um ambiente ambulatorial, com estrutura para

manejo de emergências. Atividades educacionais para mudanças de fatores de risco também são adotadas nesta fase (ACHTTIEN et al., 2015; CARVALHO et al., 2006; HERDY et al., 2014).

Pacientes que atingiram a estabilização do quadro e evoluíram nos exercícios seguem para a fase III, com duração prevista de 6 a 24 meses, ainda com supervisão de profissional especializado em exercício físico, considerada uma fase de manutenção precoce dos ganhos alcançados. A fase IV, de manutenção tardia, compreende ações a longo prazo, sem necessidade de supervisão das atividades, mas é recomendado o acompanhamento dos pacientes, com orientações a fim de assegurar o aumento e manutenção da aptidão física e mudanças permanentes com um estilo de vida saudável (CARVALHO et al., 2006; HERDY et al., 2014).

2.1.1 Reabilitação cardíaca ambulatorial supervisionada (fase II)

2.1.1.1 Indicações e contraindicações

Existe uma variabilidade pequena entre às diretrizes internacionais quanto aos pacientes que devem participar de programas de RC. Em geral se indicam pacientes após infarto agudo do miocárdio, procedimentos de revascularização do miocárdio, após correção de valvopatias ou colocação de marcapasso, pacientes com doenças cardíacas congênitas ou reumáticas, com doenças isquêmicas ou insuficiência cardíaca crônicas. Segundo as diretrizes brasileiras, há grau de recomendação A (deve ser sempre indicada) e evidência nível 1 para estas populações (CARVALHO et al., 2006).

Pacientes com doença renal crônica também apresentam indicação, com recomendação grau B (terapia que deve ser geralmente indicada) e evidência de nível 3, segundo as diretrizes nacionais de RC (CARVALHO et al., 2006). Outros pacientes considerados elegíveis para reabilitação segundo diretrizes nacionais são os que apresentem doença arterial periférica, obesidade, síndrome metabólica e diabetes melito com grau de recomendação A-B e nível de evidência 2-3 (CARVALHO et al., 2006). Doença arterial periférica também é uma indicação em alguns consensos internacionais, incluindo o Europeu (PIEPOLI et al., 2010) e o Sul-Americano (HERDY et al., 2014).

Para a fase ambulatorial, cujo foco central é a prática de exercício, deve-se considerar as contraindicações absolutas e relativas para prática de exercício, que também apresentam variações entre as diretrizes internacionais. De maneira geral, as contraindicações absolutas incluem (HERDY et al., 2014; MORAES et al., 2005):

- *Condições inflamatórias agudas:* tromboflebite, infecção sistêmica, endocardite, pericardite ou miocardite, febre de origem desconhecida;
- *Condições cardiovasculares e fatores de risco não controlados, ou controlados há menos de 72 horas:* angina instável, arritmias ventriculares graves, bloqueio atrioventricular de terceiro grau sem marca-passo, valvopatias graves com indicação cirúrgica, isquemia miocárdica com depressão do segmento ST > 2 milímetros no eletrocardiograma, insuficiência cardíaca descompensada, hipertensão arterial descontrolada (pressão arterial sistólica (PAS) $\geq$ 200 mmHg ou pressão arterial diastólica (PAD) $\geq$ 110 mmHg segundo a Diretriz Brasileira de Reabilitação Cardíaca (MORAES et al., 2005) e PAS $\geq$ 190 mmHg ou PAD $\geq$ 120 mmHg segundo a Diretriz Sul-Americana de Reabilitação Cardíaca (HERDY et al., 2014)), dissecção da aorta, embolia pulmonar, lesão de tronco de coronária esquerda instabilizada ou grave, diabetes mellitus descontrolada e outros distúrbios metabólicos não compensados);
- *Outras condições que possam impossibilitar a prática de exercício:* problemas ortopédicos ou neurológicos graves.

Herdy et al. (2014) ressaltam que várias destas contraindicações absolutas para o exercício são consideradas apenas temporárias, uma vez que superado o quadro agudo, os pacientes podem iniciar ou retomar os programas de exercício físico.

No “I Consenso Nacional de Reabilitação Cardiovascular (Fase Crônica)”, Godoy et al. (1997) incluíam como contraindicação absoluta ao exercício na RC fase II, a presença de retinopatia diabética com deslocamento de retina, entretanto, na Diretriz Brasileira de Reabilitação Cardíaca e Consenso Sul-Americano, este fator não foi listado entre as contraindicações absolutas (HERDY et al., 2014; MORAES et al., 2005). Segundo a *American Diabetes*

Association, não há evidências de que exercício aeróbico ou de força de moderada intensidade tenham qualquer efeito sobre a progressão de retinopatia diabética, embora exista contraindicação de exercício vigoroso pelo risco de risco de ruptura de vasos e hemorragia com potencial deslocamento de retina (SIGAL et al., 2006).

Godoy et al. (1997) apontam também uma lista de contraindicações relativas para a prática de exercício físico em programas de RC, incluindo arritmias específicas como extra-sístolia ventricular classe II, III e IV de Lown, arritmia supraventricular de alta frequência não controlada, bem como outras condições como aneurisma ventricular, cardiomegalia acentuada, insuficiência respiratória moderada, anemias em geral, e distúrbios mentais dependentes de terapia.

2.1.1.2 Prescrição de exercício

A padronização e elaboração de protocolos de tratamento, principalmente para a RC fase II busca a orientação dos profissionais para a adequada avaliação e prescrição do exercício a ser realizado. De maneira geral, é recomendado que as sessões iniciem com aquecimento seguido pelo treinamento aeróbico, com ou sem associação de exercício de força e desaquecimento, incluindo exercícios de flexibilidade. A prescrição da intensidade do exercício (moderada a alta intensidade) leva em consideração a performance do paciente em testes ergométricos ou ergoespirométricos prévios (ACHTTIEN et al., 2015; CARVALHO et al., 2006; HERDY et al., 2014; PIEPOLI et al., 2016). Esta recomendação é relativamente consistente entre as diretrizes europeias, norte-americanas e sul-americanas, entretanto, as diretrizes do Reino Unido, Austrália e Nova Zelândia especificam que o exercício seja realizado em baixa intensidade com menor avaliação técnica da capacidade funcional (PRICE et al., 2016).

A maioria dos estudos com programas de RC utiliza um protocolo de exercício aeróbico com duração de 20 a 40 minutos com uma intensidade moderada a alta (50-85% da frequência cardíaca (FC) máxima), podendo haver evolução ao longo do tempo de treinamento (ANDERSON et al., 2016). Estudos mais recentes demonstram que o exercício intervalado de alta intensidade pode

apresentar superioridade ao exercício contínuo de intensidade moderada em pacientes com insuficiência cardíaca, mas ainda não existem evidências suficientes para recomendação em diretrizes (ACHTTIEN et al., 2015; PIEPOLI et al., 2010).

O treinamento aeróbico pode ser disponibilizado de diversas maneiras, podendo incluir caminhadas com ou sem o uso de esteira rolante, ou uso de ciclo-ergômetro (PRICE et al., 2016). A decisão pela escolha do equipamento, entretanto, usualmente fica à critério do profissional ou do serviço, podendo muitas vezes ser influenciada mais pela disponibilidade do equipamento do que pela consideração da indicação clínica dos pacientes, sendo comumente visto na prática clínica a restrição do uso de bicicletas estacionárias aos pacientes com limitação física ou mental que impeça o treino em esteira (KLAHR et al., 2015). Ghorayeb et al. (2013) referem que a melhor forma de prescrever a intensidade de exercício aeróbico para pacientes com DCV é através da FC, utilizando uma avaliação por teste ergométrico máximo. Recomendam que a frequência cardíaca de treinamento seja calculada através da fórmula de Karvonen ($FC_{\text{treino}} = FC_{\text{reserva}} \times \text{porcentagem da FC de reserva recomendada} + FC_{\text{repouso}}$), sendo que a FC de reserva é a diferença entre FC máxima obtida no teste de esforço e a FC de repouso (GHOYAREB et al., 2013).

Outras intervenções como treinamento de flexibilidade e treinamento de força também são recomendadas na maioria das diretrizes clínicas do mundo (PRICE et al., 2016). O treinamento de força (também chamado de “resistência muscular localizada”) em geral envolve os grupamentos musculares maiores de membros superiores e inferiores e deve ser prescrito de acordo com testes específicos, como o teste de uma repetição máxima (PRICE et al., 2016), no entanto, na prática clínica a prescrição é geralmente empírica, iniciando com cargas baixas e evoluindo até que a sensação de esforço seja de baixa a moderada (CALEGARI et al., 2017; FERRAZ; YAZBEL JUNIOR, 2006).

Considerando que alguns pacientes encaminhados para RC apresentam fraqueza da musculatura inspiratória (empiricamente definida como uma avaliação da pressão inspiratória máxima menor que 70% do predito (RIBEIRO; CHIAPPA; CALLEGARO, 2012) ou menor que 60 cmH₂O (GOSSELINK et al., 2011), avaliada através de manuvacuometria), o treinamento muscular inspiratório (TMI) pode ser considerado como uma opção

terapêutica na reabilitação cardíaca. Benefícios do TMI em pacientes com insuficiência cardíaca já foram verificados por Plentz et al. (2012) em uma metanálise identificando melhora significativa da capacidade funcional avaliada pelo consumo máximo de oxigênio e teste de caminhada de 6 metros e força muscular inspiratória, embora com baixa qualidade de evidência avaliada pelo sistema GRADE. Smart, Giallauria, Dieberg et al. (2013b) reportaram resultados semelhantes e acrescentam que TMI apresenta melhora do equivalente ventilatório de dióxido de carbono. De maneira similar, Wu, Kuang e Fu (2018) demonstram que TMI, principalmente com duração de treinamento maior que 6 semanas é capaz de melhorar a função pulmonar, tolerância ao exercício e qualidade de vida de pacientes com insuficiência cardíaca.

Sbruzzi et al. (2012) verificaram através de uma revisão sistemática que o TMI não demonstrava diferença em comparação com controle para melhora da qualidade de vida em pacientes com insuficiência cardíaca. Entretanto, Neto et al. (2018) conduziram uma metanálise para verificar o efeito adicional do TMI ao exercício físico em pacientes com insuficiência cardíaca, incluindo evidências mais recentes e verificaram melhora significativa na força da musculatura inspiratória e qualidade de vida dos pacientes. A diretriz Holandesa de RC incluiu a recomendação de TMI para pacientes com insuficiência respiratória ou fraqueza da musculatura inspiratória (ACHTTIEN et al., 2015).

Outra forma de incrementar a RC e providenciar alternativas de intervenções para pacientes com DCV mais graves ou outras condições que comprometam sua capacidade de exercício ativo é a eletroestimulação neuromuscular (EENM) ou eletroestimulação funcional (*functional electrical nerve stimulation* – FES) (KLAHR, 2014). Previamente nosso grupo de pesquisa verificou através de metanálise que EENM em pacientes com insuficiência cardíaca em comparação com exercício aeróbico ou controle não apresentou diferença quanto à força e capacidade funcional avaliada pela distância percorrida no teste de caminhada de 6 minutos, mas apresenta um ganho menor no pico de consumo de oxigênio (SBRUZZI et al., 2010).

Smart, Dieberg e Giallauria (2013a) também conduziram uma metanálise para verificar o efeito da adição de EENM na RC de pacientes com insuficiência cardíaca em comparação com exercício convencional ou placebo e

verificou que, embora os benefícios do EENM não tenham magnitude semelhante ao exercício ativo, EENM pode ser uma intervenção preferível para os pacientes que não conseguem se exercitar ativamente ou deve ser utilizado de maneira complementar ao exercício ativo. Os autores verificaram que o tempo total de estimulação apresentou uma correlação positiva forte com aumento no pico de consumo de oxigênio, indicando maiores benefícios na resistência cardiorrespiratória com estimulação mais prolongada (SMART; DIEBERG; GIALLAURIA, 2013a).

Mais recentemente Gomes Neto et al. (2016) publicaram outra metanálise sobre o assunto reportando que EENM é inferior ao exercício aeróbico para melhora do consumo de oxigênio pico, mas superior à controle sem exercício em pacientes com insuficiência cardíaca (GOMES NETO et al., 2016). Além disto, não foi verificada diferença quanto à distância percorrida no teste de caminhada de 6 minutos ou em qualidade de vida com uso de EENM em comparação com exercício aeróbico, mas superioridade da mesma para os dois desfechos em comparação com controle sem exercício (GOMES NETO et al., 2016).

2.2 SISTEMAS DE APOIO À DECISÃO

SAD é um termo geral para qualquer aplicação computacional que aprimore as habilidades de um indivíduo ou grupo para a tomada de decisão (POWER; SHARDA; BURSTEIN, 2015). Na prática clínica os SAD suportam funções cognitivas complexas envolvidas no diagnóstico clínico e prescrição de tratamento, como raciocínio, aprendizagem e processos de tomada de decisão (LINDGREN, 2007). Os SAD clínicos podem ser desenvolvidos com diferentes propósitos incluindo prevenção e rastreamento, dosagem de drogas, controle de doenças crônicas, diagnóstico e tratamento, considerando pacientes tanto em ambiente hospitalar quanto ambulatorial (WRIGHT et al., 2011). Além disto, podem ser desenvolvidos para diferentes usuários, incluindo profissionais da área da saúde e os próprios pacientes (SEIXAS et al., 2014).

O desenvolvimento dos SAD, inicia com a identificação do cenário de utilização do sistema, incluindo quem será o usuário e qual o propósito de uso

(JOHNSON; ZHENG; PADMAN, 2014). Considerando seu propósito, existem cinco tipos mais específicos de SAD (POWER; SHARDA; BURSTEIN, 2015):

- a) SAD orientado a comunicação (*communications-driven decision support system (DSS)*): utiliza tecnologias de rede e comunicações para facilitar e aumentar a colaboração, compartilhamento de informações e tomada de decisão compartilhada;
- b) SAD orientado a dados (*data-driven DSS*): tem ênfase no acesso e manipulação de dados internos ou externos. Modelos mais básicos incluem sistemas de acesso por consulta e ferramentas de recuperação de dados históricos. Funcionalidades mais avançadas nestes SAD incluem processamento analítico online de grandes coleções de dados históricos. Alguns destes SAD utilizam dados em tempo real para assistência e monitoramento operacional;
- c) SAD orientado a documentos (*document-driven DSS*): integra uma variedade de tecnologias de armazenamento e processamento para prover completa recuperação e análise de documentos para assistir à tomada de decisão. A internet fornece acesso à grandes bancos de dados de documentos, podendo ser citado como um exemplo na área da saúde o MEDLINE (*Medical Literature Analysis and Retrieval System Online* – Sistema Online de Busca e Análise de Literatura Médica);
- d) SAD orientado a conhecimento (*knowledge-driven DSS*): utiliza tecnologias de inteligência artificial e inferência estatística para sugerir ou recomendar ações. Estes SAD apresentam conhecimento codificado para prover assistência à solução de problemas especializados;
- e) SAD orientado a modelos (*model-driven DSS*): focado no acesso e manipulação de um modelo quantitativo. Em geral estes sistemas utilizam modelos financeiros, simulações e/ou modelos de otimização para providenciar suporte à decisão. Este tipo de SAD utiliza parâmetros providos por tomadores de decisão para auxiliá-los a analisar uma situação.

Os SAD para prática clínica com maior potencial de efetividade são os orientados ao conhecimento, pois têm a característica de prover recomendações e não apenas avaliações (ROSHANOV et al., 2013). SAD clínicos também podem ser classificados de acordo com sua forma de representar o conhecimento (KONG; XU; YANG, 2008) em:

- a) Sistemas baseados em regras (*rule-based systems*): utilizam expressões lógicas condicionais (isto é, se-então-senão) para gerar deduções e auxiliar decisão clínica;
- b) Sistemas baseados em diretrizes clínicas (*clinical guidelines-based systems*): indicam uma decisão clínica mais provável ou uma opção de caminho a ser seguido entre um conjunto de opções pré-determinadas, guiadas por um fluxograma que descreve, por exemplo, regras diagnósticas ou etapas sequenciais de um tratamento;
- c) Sistemas baseados em redes semânticas (*semantic network-based systems*): utilizam relações semânticas entre conceitos para compor um algoritmo de inferência (um grafo direcionado).

Sistemas baseados em RB caem na categoria de sistemas semânticos, uma vez que os seus nós representam conceitos clínicos e os arcos representam relações causais entre os conceitos (SEIXAS et al., 2014).

2.2.1 Sistema de apoio à decisão baseado em rede probabilística

O cenário de decisão clínico é caracterizado pela presença de incertezas e causalidade, o que torna as redes probabilísticas adequadas para a construção de SAD clínicos (SEIXAS et al., 2014), uma vez que são consideradas métodos representativos do conhecimento incerto, ao permitir representar e manipular a incerteza com base em princípios matemáticos fundamentados (FLORES et al., 2000; PEARL, 2009). A aplicação do Teorema de Bayes nas redes probabilísticas permite abordar as incertezas através de probabilidades que podem atuar de forma isolada ou encadeada (quando um evento reforça ou diminui a probabilidade de outro), na construção de um raciocínio. Este raciocínio se baseia em inferências probabilísticas, isto é, na

probabilidade condicional de um evento, influenciada por todas as evidências disponíveis (FLORES et al., 2000; VERDUIJN et al., 2007).

2.2.1.1 Rede Bayesiana

A RB é um modelo gráfico que representa as relações probabilísticas e independência condicional entre as variáveis. A estrutura da RB consiste de **grafos acíclicos** compostos por **nós** que representam as variáveis (nós de incerteza), e **arcos direcionados** que representam as suposições de independência condicional entre as variáveis. (YET et al., 2013).

Grafos podem ser considerados como uma noção abstrata e intuitiva de representar relações entre “objetos” (ou variáveis, ou conceitos) de um determinado conjunto. Podem ser representados graficamente por dois componentes principais, os nós ou vértices (que representam os objetos) unidos por traços que são chamados arestas ou arcos (que representam as relações entre os objetos). Quando as relações entre os objetos apresentam um caminho orientado, as arestas são representadas com flechas indicando a direção da relação, e os grafos são denominados direcionados, ou orientados. Ou seja, dados os nós “A” e “B”, ligados por um arco direcional “ $A \rightarrow B$ ”, pode se dizer que “A” é antecessor ou **pai** de “B” e “B” é sucessor ou **filho** de “A”. Um grafo orientado para ser considerado acíclico não pode apresentar caminhos que formem circuitos fechados, como por exemplo, dados os nós “A”, “B” e “C”, a existência de arcos direcionais “ $A \rightarrow B$ ”, “ $B \rightarrow C$ ” e “ $C \rightarrow A$ ” representa um circuito fechado de relação entre os objetos (JEQUESSNE, 2010).

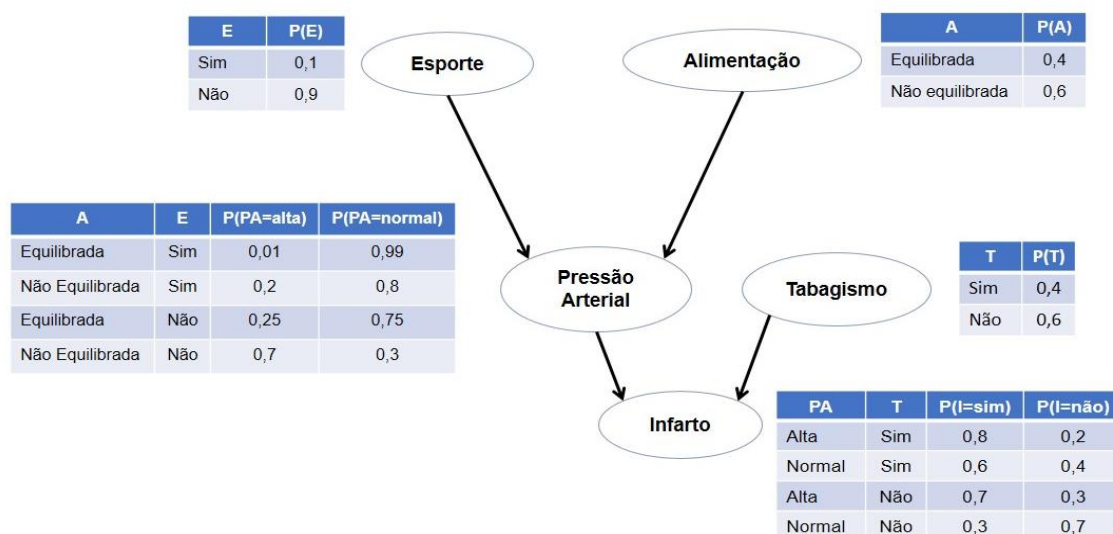
Cada nó pertencente à RB possui um conjunto de estados mutuamente exclusivos e coletivamente exaustivos com distribuição de probabilidades condicionais aos estados dos seus nós pais (também chamadas de probabilidades “a posteriori”), ou com probabilidades não-condicionais no caso de o nó não possuir pais (também chamadas de probabilidades “a priori”) (FLORES et al., 2000; PEARL, 2009; YET et al., 2013). A RB proporciona grande liberdade de uso pois não necessita a observação de todos os nós para gerar um resultado, ao calcular a distribuição de probabilidades posteriores dos nós não observados dados os estados de nós que foram observados. Desta forma,

a RB pode ser usada tanto para diagnóstico quanto para predição, dependendo das observações disponíveis (YET et al., 2013).

Na Figura 1, a seguir, está representado um exemplo de rede Bayesiana, onde elipses representam os nós de incerteza, tabelas representam as probabilidades condicionais ou não-condicionais de cada estado dos nós e as flechas representam os arcos direcionados.

Neste exemplo, pode-se verificar que “Esporte”, “Alimentação” e “Tabagismo” são nodos que não tem pais e, portanto, apresentam probabilidades não-condicionais para seus respectivos estados. O nodo “Pressão Arterial” é filho de “Esporte” e “Alimentação”, assim sendo, seus estados apresentam probabilidades condicionais dados os estados de seus pais. Da mesma forma, “Infarto” apresenta probabilidade condicional de seus estados dados os estados de seus pais “Pressão Arterial” e “Tabagismo”.

Figura 1 – Exemplo de rede Bayesiana



Fonte: Autoria própria.

A: Alimentação; E: esporte; P: probabilidade; PA: Pressão Arterial; T: Tabagismo.

As probabilidades relacionadas a cada estado podem ser aprendidas pela máquina a partir de dados disponíveis, estimada por experts de domínio ou obtidas na literatura (YET et al., 2013). O DI desenvolvido por Klahr et al. (2015) teve suas probabilidades aprendidas de um banco de dados de uma coorte de pacientes que compareceram ao encaminhamento a um centro de RC

de referência em Porto Alegre, o Centro de Reabilitação Cardiopulmonar e Metabólica pertencente ao hospital Instituto de Cardiologia do Rio Grande do Sul.

As RB tornam-se adequadas para SAD através da construção de um DI, que segue a teoria clássica de decisões para formalizar um problema de tomada de decisão incluindo variáveis de decisão e funções de utilidade em uma generalização da RB (FLORES et al., 2000; LUCAS; VAN DER GAAG; ABU-HANNA, 2004; PEARL, 2009).

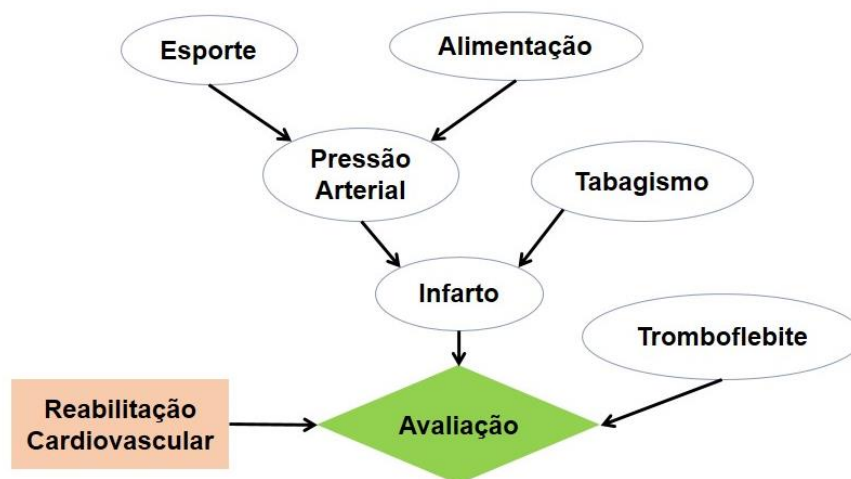
2.2.1.2 Diagrama de Influências

Um DI, assim como uma RB, também pode ser descrito como um grafo acíclico direcionado, que além dos nós de incerteza (tais quais os nós descritos nas RB, com probabilidades condicionais ou não-condicionais de acordo com as relações parentais dos nós), inclui nós “especiais”, os nós de **utilidade** e os nós de **decisão**. Utilidade pode ser definida como uma medida da preferência de um sujeito dada uma certa condição. Nós de utilidade incorporam uma função de utilidade contendo a descrição da utilidade do decisor em função da combinação de estados dos seus nós pais (JEQUESSENE, 2010). Os nós de utilidade podem ser filhos de nós de decisão e de nós de incerteza, não podem ter filhos e não têm estados associados, mas levam a informação da utilidade ao nó de decisão (KLAHR, 2014).

Nós de decisão, que representam pontos de escolha de ações com um conjunto finito de estados mutuamente exclusivos, são representados graficamente por retângulos. Seus nós pais podem ser outros nós de decisão ou nós de incerteza (JEQUESSENE, 2010).

Na Figura 2 apresentamos um exemplo de DI, onde elipses representam nós de incerteza (que, embora não apresentadas graficamente possuem uma tabela de probabilidades condicionais ou não-condicionais para seus estados tal qual apresentado anteriormente na Figura 1), o losango representa um nó de utilidade, e o retângulo um nó de decisão.

Figura 2 – Exemplo de diagrama de influências



Fonte: Autoria própria.

Neste exemplo, o nó de decisão apresenta dois estados mutuamente exclusivos, indicação ou contra-indicação. Através da função de utilidade “Avaliação”, a recomendação para a decisão se vale da utilidade determinada em condição dos estados dos nós pais ligados à “Avaliação”, no exemplo “Infarto” e “Tromboflebite”. Vale lembrar que “Infarto” é filho de “Pressão Arterial” e “Tabagismo” e, desta forma, apresenta probabilidades condicionais para os seus estados, dadas as probabilidades dos estados de seus nós pais.

A aplicabilidade dos DI é ampliada pela sua característica de possibilitar a inserção de **evidências** que são observações dos estados dos nós de incerteza. A inserção de evidências na rede se dá pelo instanciamento de um estado para o nó. Este estado observado passa a ter uma probabilidade de 1 (100%) o que representa uma certeza. Dada esta evidência inserida, o DI, da mesma forma que uma RB, calcula as novas probabilidades para os estados dos nós que não foram observados, ou seja, propaga as evidências na rede (FLORES et al., 2000). Esta propagação pode alterar a recomendação de um DI, uma vez que a função de utilidade leva em consideração as incertezas dos estados de seus nós pais para a recomendação. É possível inserir evidências para qualquer número de nós de incerteza em qualquer parte do DI e recalculando a probabilidade condicional para os demais nodos (YET et al., 2013).

Os produtos comerciais mais importantes para elaboração de redes probabilísticas são os sistemas HUGIN¹ (Hugin Expert A/S, Dinamarca) e o Netica² (Norsys Software Corporation, Noruega). O software livre HUGIN foi utilizado para o desenvolvimento dos DI que formam a base de conhecimento deste SAD (KLAHR et al., 2015). No Brasil, foi desenvolvido um *software* livre, com código aberto (código inteiramente disponível), baseado em linguagem Java para modelagem, aprendizagem e raciocínio sobre redes probabilísticas, o UNBBayes. O *software* oferece uma plataforma *Graphical User Interface (GUI)* (um tipo de plataforma que permite o usuário interagir com o programa através de imagens ao invés de linhas de comando), bem como uma *Application Program Interface (API)* (uma interface implementada por um *software* que permite sua interação com outro *software*) (MATSUMOTO et al., 2011).

2.2.2 Ciclo de vida do Desenvolvimento de *Softwares*

Em geral o ciclo de vida do desenvolvimento de *softwares* pode ser descrito como o processo em etapas da construção ou manutenção de *softwares* (LEAU et al., 2012). Embora existam diferentes metodologias de desenvolvimento de *software*, algumas etapas do desenvolvimento são comuns a todas, mas dependendo da metodologia, as etapas não são executadas sequencialmente, mas de maneira iterativa (MAHAPATRA; GOSWAMI, 2015). Podem ser destacados quatro conjuntos de etapas principais:

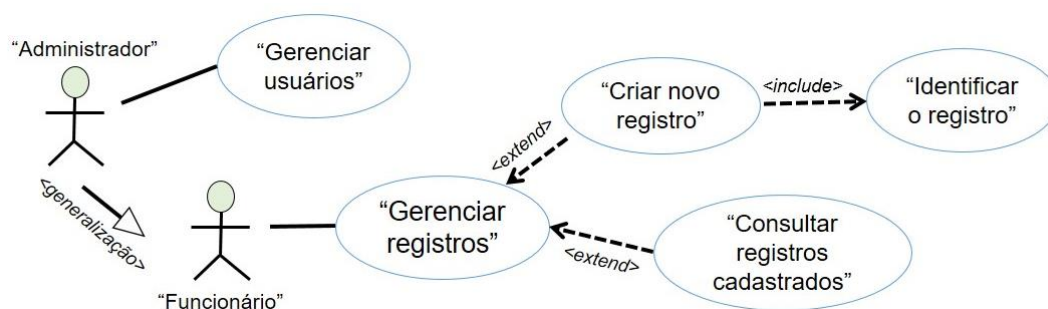
- a) *Idealização/Concepção*: Ideia do *software*, qual seu propósito de uso e importância para o contexto definido, bem como a definição da equipe de trabalho (MAHAPATRA; GOSWAMI, 2015);
- b) *Análise*: compreende a avaliação de requisitos funcionais e não funcionais, e análise de casos de uso. A análise de requisitos busca compreender as necessidades dos usuários, levando em consideração o contexto no qual o *software* estará inserido, identificando as funcionalidades mais importantes do sistema (LACERDA, 2007; GUEDES, 2011), podendo ser considerado como a representação em palavras do *software* idealizado. Requisitos

¹ HUGIN (<https://sourceforge.net/projects/hugin/>)

² Netica (<https://www.norsys.com/netica.html>)

funcionais expressam funções ou serviços que o *software* deve ser capaz de oferecer e requisitos não funcionais declaram restrições de funções do *software* ou atributos de qualidade para o *software*, por exemplo, segurança, precisão e desempenho (CYSNEIROS, et al., 2001). De acordo com Serna E., Bachiller e Serna A. (2017), a especificação de requisitos, como produto da engenharia de requisitos é amplamente aceita pela comunidade de desenvolvimento de software, como o estágio do ciclo de vida com maior impacto na qualidade do produto final. Através da análise de casos de uso (qual a relação dos usuários com as funcionalidades do *software*) pode-se construir um diagrama de casos de uso, que descreve as interações entre atores e o sistema (SHEN; LYU, 2003). O diagrama de caso de uso é o mais geral e informal da UML (*Unified Modeling Language*) (GUEDES, 2011), uma linguagem de modelagem que pode ser aplicada ao desenvolvimento de softwares através de modelos do design seguindo uma mesma estrutura (SHEN; LYU, 2003). Inclui bonecos que representam os atores, (usuários externos ou outros sistemas), flechas que representam as relações entre casos de uso ou entre atores e elipses que contém a descrição dos casos de uso. As relações podem ser do tipo “include” (casos de uso que são indispensáveis, [ocorrendo sempre] em função de outro caso de uso), “extend” (casos de uso opcionais) ou “generalização” (quando um caso de uso ou ator apresenta as mesmas especificações que outro já definido no diagrama) (GUEDES, 2011), conforme pode ser verificado na figura 3 a seguir.

Figura 3 – Exemplo de diagrama de casos de uso



Fonte: Autoria própria.

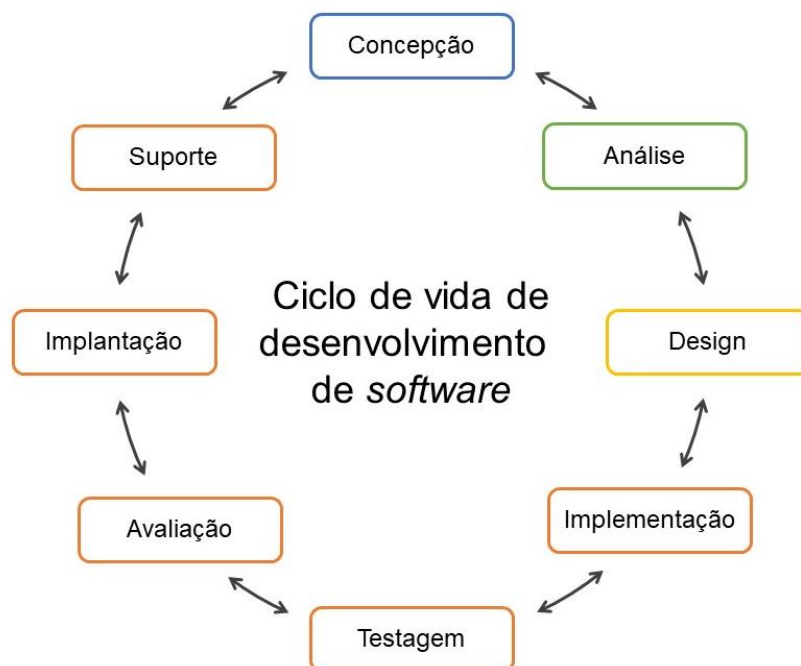
Neste exemplo, foram representadas as relações entre casos de uso hipotéticos. A funcionalidade principal que pode ser executada pelo ator “Funcionário” é “Gerenciar registros”. Neste caso de uso, estão ligados dois outros casos de uso opcionais, portanto, ligados por “*extend*”: “Criar novo registro” e “Consultar registros cadastrados”. Sempre que o “Funcionário” “Criar novo registro” ele deverá “Identificar o registro”, portanto estes casos de uso foram ligados com um “*include*”. A “generalização” representada entre o “Administrador” e o “Funcionário” indicam que o “Administrador” tem acesso aos mesmos casos de uso do que o “Funcionário” e ainda apresenta um caso de uso que o “Funcionário” não tem acesso, que é “Gerenciar usuários”.

c) *Design*: determina como o sistema irá operar (em termos de *software*, *hardware* e infraestrutura de rede), a interface do usuário e os programas específicos, bases de dados e arquivos que serão necessários (MAHAPATRA; GOSWAMI, 2015);

d) *Implementação*: durante esta fase, o sistema é realmente construído. Inclui a codificação, teste, liberação da versão final, disponibilização do sistema (implantação), manutenção e melhoramentos (MAHAPATRA; GOSWAMI, 2015).

A figura 4, a seguir, apresenta um resumo das etapas descritas acima. As cores azul, verde, amarelo e laranja representam respectivamente as etapas ‘a’, ‘b’, ‘c’ e ‘d’. As flechas bidirecionais representam a possibilidade de iteratividade no processo. É importante ressaltar que este trabalho compreende as etapas iniciais do desenvolvimento de um *software*, no caso as etapas de concepção, análise e parte da etapa de design, incluindo os designs da arquitetura e da interface gráfica do *software*.

Figura 4 – Representação de etapas do ciclo de vida de desenvolvimento de *software*



Fonte: Autoria própria.

O desenvolvimento do SAD objeto deste trabalho segue a metodologia Scrum, uma metodologia de desenvolvimento e administração das etapas de construção de um *software* que observa os princípios dos métodos ágeis, os quais são baseados na ideia de desenvolvimento incremental e iterativo, onde as fases dentro do ciclo de vida do desenvolvimento são revisitadas diversas vezes (LEAU et al., 2012).

2.2.2.1 Scrum

Um projeto com metodologia Scrum inicia com a definição do sistema que será realizado, que se refere à etapa de concepção e análise descritas acima. Então, se define um “*backlog*” do produto (uma lista de tudo que se define como necessário no sistema). O *backlog* do produto lista todas as funcionalidades, funções, requisitos, melhoramentos e consertos que constituem as mudanças a serem feitas no produto em liberações futuras. Ele segue uma ordem de prioridades para o sistema, iniciando com o design do software (fluxo do sistema, interfaces e bases de dados). Uma vez que o design é definido,

inicia-se a codificação até que o sistema possa ser testado. O processo se repete até que o sistema atinja as funcionalidades definidas. Entretanto, enquanto existe um produto, existe um *backlog*, podendo ser alterado em função de mudanças econômicas, avanços tecnológicos, novas funcionalidades, e outros (SCHWABER; SUTHERLAND, 2017). Existe um termo na metodologia Scrum chamado “*sprint*”, que se refere a uma série de objetivos (tarefas do *backlog*) que devem ser alcançados em um período determinado. Reuniões para definição dos *sprints* podem ter um intervalo pré-definido e a revisão do progresso no *sprint* idealmente deve ser realizada diariamente.

O monitoramento do desenvolvimento se dá através de um quadro que contém o *backlog* do produto levando em consideração os *sprints* determinados, organizado em colunas que incluem tarefas planejadas, tarefas em progresso, tarefas finalizadas, problemas (ou “*bugs*”) identificados e extras. Conforme ocorre o desenvolvimento, as tarefas vão progredindo entre as colunas, podendo ser adicionadas novas tarefas e redirecionadas as prioridades durante o processo de desenvolvimento e não apenas na fase de planejamento do software (PERMANA, 2015).

2.3 SISTEMAS DE APOIO À DECISÃO EM REABILITAÇÃO CARDÍACA

Para identificar SAD para RC desenvolvidos previamente, foi conduzida uma busca sistemática em bases de dados eletrônicas da área da saúde Medline (via Pubmed), *Cochrane Central Register of Controlled Trials* (CENTRAL), EMBASE, *Physiotherapy Evidence Database* (PEDro) e em bases de dados da área da informática (*IEEEExplore* e *Science Direct*). A estratégia de busca utilizou termos indexados e seus sinônimos incluindo “Decision Support Systems, Clinical” e “Cardiac Rehabilitation”, combinados com termos booleanos “AND” e “OR”, sem restrição de data de publicação ou linguagem (do início das bases de dados até 25 de março de 2018). Os termos foram adaptados as características de cada base de dados. O quadro 1 apresenta a estratégia de busca utilizada no PubMed.

Quadro 1 – Estratégia de busca para base de dados Medline acessada via PubMed.

Identificador	Estratégia
# 1	<i>“Decision Support Systems, Clinical”[Mesh] OR “Clinical Decision Support System*” OR “Clinical Decision Support” OR “CDSS” OR “Decision Support System*” OR “DSS”</i>
# 2	<i>“Cardiac Rehabilitation”[Mesh] OR “Cardiac Rehabilitation*” OR “Cardiovascular Rehabilitation*” OR “Outpatient Cardiac Rehabilitation*”</i>
# 3	#1 AND #2

Fonte: Autoria Própria

A busca nas bases de dados resultou em 144 registros. Após sua revisão, foram identificados 3 SAD relacionados à RC, dois voltados para apoio à decisão de profissionais (CARDSS e EXPERT), e um para tele-reabilitação (PATHway).

CARDSS (*Cardiac Rehabilitation Decision Support System*) é um sistema de registro de pacientes com funcionalidades de apoio à decisão baseado em diretriz para dar suporte a todo o processo de RC, com foco na avaliação dos pacientes quanto sua necessidade de reabilitação e para aumentar a aderência à diretrizes durante a reabilitação. O CARDSS foi desenvolvido para uso em computador, incluindo um registro dos pacientes, que pode ser acessado e modificado por todos os profissionais de saúde envolvidos na RC do paciente e provendo recomendações baseadas na formalização do conhecimento de diretrizes clínicas, com explicações para as recomendações. Este sistema foi distribuído gratuitamente para hospitais holandeses que aceitassem participar de um ensaio clínico randomizado e também poderia ser comprado no país (GOUD; HASMAN; PEEK, 2008).

A aderência à diretrizes clínicas holandesas para RC com suporte do CARDSS foi investigada em um ensaio clínico randomizado, incluindo 31 centros de reabilitação da Holanda. Os centros foram randomizados para utilização de duas versões do CARDSS, uma completa, com recomendações e uma versão controle, que permitia o uso do registro de pacientes, mas não previa nenhuma recomendação. O uso do SAD aumentou significativamente a

conformidade com as recomendações da diretriz para exercício em 3,5%, medidas educativas em 23,7% e para terapias de relaxamento em 41,6% (GOUD et al., 2009).

EXPERT (Exercise Prescription in Everyday Practice and Rehabilitative Training) é um SAD e treinamento digital para prescrição de exercício, desenvolvido por um grupo de especialistas em reabilitação de doenças crônicas de 11 países europeus (grupo EXPERT), com endossamento da *European Association of Preventive Cardiology*. O SAD foi desenvolvido para uso em computador, com sua base de conhecimento baseada em diretrizes, sendo desenvolvido para apoio à decisão de profissionais de saúde envolvidos diretamente em RC na escolha e adoção da opção de treinamento otimizada para um paciente. O profissional pode selecionar uma ou mais opções para caracterizar o paciente, que incluem DCV, fatores de risco para DCV e outras condições que possam afetar a prescrição de exercício. Ainda, o profissional pode inserir as medicações em uso e eventos adversos durante o teste de esforço. Após a informação destas características, o EXPERT apresenta uma prescrição de exercício (intensidade de treinamento, frequência, duração, tipo, número de sessões e duração do programa e modalidades extra de exercício) baseada em diretrizes clínicas para RC. A implantação deste sistema deve ocorrer em clínicas de reabilitação da Europa (HANSEN et al., 2017).

PATHway (*Physical Activity Towards Health*) é um SAD desenvolvido para apoio à RC não supervisionada em casa (tele-reabilitação), na fase III destes programas (após reabilitação ambulatorial). O SAD foi desenvolvido a partir de diretrizes internacionais de RC e opinião de experts, sendo um SAD baseado em regras. Ele utiliza sensores de frequência cardíaca, pressão arterial e de movimento para controle dos parâmetros clínicos e correta execução dos exercícios, e personalização da prescrição de exercício. A reabilitação funciona através de sessões de exercícios curtos programadas em uma interface de jogo com uma série de exercícios de curta duração, de diferentes intensidades e dificuldades, envolvendo diferentes partes do corpo para adequar a intensidade do treinamento prescrito (150 minutos de exercício de moderada intensidade semanalmente) à frequência cardíaca de trabalho intencionada (CHATZITOFIS et al., 2017; FILOS et al., 2016; TRIANTAFYLLIDIS et al., 2018). Este sistema foi investigado em um estudo piloto incluindo 10

pacientes e foi considerado seguro e com potencial benefício clínico na reabilitação não supervisionada de pacientes com DCV. Este sistema não foi disponibilizado para uso até o momento. Está planejada a condução de um ensaio clínico randomizado para avaliar sua validade como ferramenta de tele-reabilitação cardíaca (TRANTAFYLLIDIS et al., 2018).

No quadro 2 está apresentado um resumo das características dos sistemas identificados na busca. É importante salientar que não foi identificado nenhum SAD em RC, que tenha como base de conhecimento redes probabilísticas, para uso em dispositivos móveis e com disponibilidade no Brasil ou mesmo na América do Norte ou América Latina.

Quadro 2 – Resumo de características dos sistemas de apoio à decisão existentes

Software	Tipo de SAD	Forma de representar o conhecimento	Público-alvo	Fase de Reabilitação Cardíaca (classificação nacional)	Dispositivo de uso	Local de Implantação
CARDSS	Orientado a dados e conhecimento	Baseado em diretrizes	Profissionais de centros de reabilitação cardíaca	Fase II (ambulatório supervisionado)	Computador	Holanda
EXPERT	Orientado a conhecimento	Baseado em diretrizes	Profissionais de centros de reabilitação cardíaca	Fase II (ambulatório supervisionado)	Computador	Europa
PATHway	Orientado a conhecimento	Baseado em regras	Pacientes de centros de reabilitação cardíaca	Fase III (tele-reabilitação)	Vídeo-game (Xbox One)	Europa

Fonte: Autoria própria.

3 JUSTIFICATIVA

As DCV apresentam altas taxas de mortalidade no mundo (PRICE et al., 2016) e no Brasil (BRANT et al., 2017), além disto, há um crescente número de pacientes que sobrevivem a eventos agudos e passam a viver com DCV crônicas (ANDERSON et al., 2016), sendo necessárias medidas para melhora de sua qualidade de vida e retorno às atividades normais (MORAES et al., 2005). A RC é uma das intervenções mais recomendadas internacionalmente para prevenção secundária de DCV (ACHTTIEN et al., 2015; CARVALHO et al., 2006; EZEKOWITZ et al., 2017; HERDY et al., 2014; MORAES et al., 2005; PIEPOLI et al., 2010; SMITH et al., 2011; THOMAS et al., 2010). A aderência a programas de RC baseados em exercício promove melhoras na capacidade de exercício e resistência cardiovascular além de redução nos fatores de risco cardiovascular, bem como estresse psicossocial e consequente redução da mortalidade cardiovascular e taxas de hospitalização além de aumentar a expectativa e qualidade de vida (ACHTTIEN et al., 2015; DAVIES et al., 2010; LAVIE et al., 2016; MORAES et al., 2005).

A RC ambulatorial supervisionada apresenta-se como um cenário de decisão complexo, sendo necessário definir se o sujeito apresenta indicação para reabilitação, considerar as possíveis contraindicações para a prática de exercício além da determinação das intervenções a serem realizadas. Embora existam alguns SAD disponíveis para apoio à decisão em RC ambulatorial supervisionada, suas bases de conhecimento são formuladas a partir de diretrizes clínicas, considerando apenas os fatos informados para a formulação de recomendações, além de estarem disponíveis apenas para uso em computador (GOUD; HASMAN; PEEK, 2008; TRIANTAFYLLIDIS et al., 2018).

Seguindo os pressupostos da prática baseada em evidência, que visam a utilização da melhor evidência clínica disponível, somada à experiência clínica profissional e valores e preferências dos pacientes para a tomada de decisão na prática clínica (SACKET et al., 1996), percebe-se uma inerente incerteza e condicionalidade das decisões na prática clínica, dado que as evidências científicas ficam em constante evolução e cada paciente é um indivíduo com seus próprios valores e preferências. Pode-se dizer que ao longo do tempo, conforme a experiência clínica profissional aumenta, fortalecem-se as

crenças e diminuem-se as incertezas na tomada de decisão, entretanto, sempre haverá certo grau de incerteza nas decisões (KLAHR et al., 2015).

Os DI construídos por Klahr et al. (2015) vêm ao encontro desta realidade, fornecendo uma formalização do problema de tomada de decisão quanto à indicação do paciente à RC e qual a melhor combinação de intervenções para seu treinamento na RC ambulatorial. Os DI gerados foram validados por especialistas e através de um banco de dados de um centro de RC de Porto Alegre, e foram considerados representativos do pensamento clínico (KLAHR et al., 2015).

A utilização dos DI previamente propostos no desenvolvimento de um SAD possibilita uma nova abordagem, levando em consideração a incerteza para gerar recomendações no contexto de RC ambulatorial supervisionada. Seu desenvolvimento para uso em dispositivos móveis e a inclusão de definições para as variáveis disponibilizadas no *software* fortalecem as chances de sucesso com o seu uso, uma vez que a capacidade de prover recomendações no momento e local da tomada de decisão (ROSHANOV et al., 2013) e o aprendizado gerado com o seu uso (VERDUIJN et al., 2007) são dois fatores determinantes de sucesso no uso de SAD clínicos. Desta forma, este trabalho foi conduzido para responder à questão: “quais são as principais funcionalidades, arquitetura e interface gráfica necessárias para o desenvolvimento de um SAD que utilize DI como base de conhecimento no apoio à tomada de decisão em RC ambulatorial supervisionada para uso em dispositivos móveis?”.

4 OBJETIVOS

4.1 OBJETIVO GERAL

Conceber um SAD para suporte à decisão em RC ambulatorial supervisionada, baseado em redes probabilísticas.

4.2 OBJETIVOS ESPECÍFICOS

- Conceber o software, definindo suas principais características, público-alvo e aplicabilidade;
- Identificar os requisitos funcionais e não funcionais para o desenvolvimento do *software*;
- Descrever os casos de uso para a modelagem do *software*;
- Criar o design da arquitetura do *software*, identificando os componentes principais e suas relações;
- Criar o design da interface gráfica do *software*;
- Desenvolver definições simplificadas para as variáveis dos DI que são a base de conhecimento do software.

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6 ARTIGO

CARDIODSS: CONCEPT, REQUIREMENTS AND DEVELOPMENT METHODOLOGY OF AN M-HEALTH DECISION SUPPORT SYSTEM FOR SUPERVISED OUTPATIENT CARDIAC REHABILITATION

(A ser submetido ao periódico Health Informatics Journal)

(Fator de impacto em 2016: 3.021. Não apresenta avaliação no QUALIS para área 21)

Article type: Original Research

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CardioDSS: concept, requirements and development methodology of an m-health decision support system for supervised outpatient cardiac rehabilitation

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Abstract

In this study, we described the concept, requirement analysis, development methodology, architectural and interface design of a mobile-based, knowledge-driven clinical decision support system for professionals from supervised outpatient cardiac rehabilitation programs (the Cardiovascular Rehabilitation Decision Support System - CardioDSS). Two influence diagrams with Bayesian inference composes the knowledge base for the application. The development is following the Scrum methodology and is currently under implementation process. The functionalities of CardioDSS include personal account management; creation, storage and management of patient records including clinical characteristics that will influence the recommendations; easy access to the recommendations, without creation of a patient and data storage; influence diagram processing, with recommendations in graphics and possibility of export of the results to a portable document file. The software architecture includes a graphic user interface for Android devices and two servers, for data storage and influence diagram processing.

Keywords

Cardiovascular Diseases; Cardiac Rehabilitation; Decision Support Systems, Clinical; Bayes Theorem; Influence Diagrams; Software Design; Mobile Applications.

Introduction

Cardiovascular diseases are a principal cause of mortality worldwide and the most prevalent non-communicable diseases.^{1, 2} The cardiac rehabilitation (CR) programs emerged as a multidisciplinary and comprehensive intervention to improve the physical, mental and social capabilities of patients with cardiovascular diseases,³ been the exercise, lifestyle changes, and risk factor management their central components.⁴ The adherence to exercise-based CR programs can improve exercise capability, cardiovascular resistance, and quality of life, reduce cardiovascular risk factors, stress,^{5, 6} cardiovascular mortality and hospital readmission,⁴ and increase life expectancy by about two years.⁷ They are composed by three or four stages, varying across guidelines. Independently of the classification, there is a consensus that after the hospital discharge, the patients should be referred to a supervised outpatient exercise-based CR (from now on referred only as CR).^{6, 8-13} The decision-making process in CR is complex, being necessary specialized knowledge about the clinical characteristics of the patients, risk factors and comorbidities that may restraint the physical training, besides the proper physical training prescription for each patient.¹⁴⁻¹⁶

The decision support systems (DSS) – defined as any computational applications that improve the abilities of an individual or group to make decisions¹⁷ – can be applied in clinical practice, potentially increasing the health care quality,¹⁸⁻²⁰ reducing diagnostic errors,²¹ increasing conformity with clinical guidelines and consequently the health of the patients.^{22, 23} There are different types of DSS, but the most suitable for clinical DSS is the knowledge-driven, that uses artificial intelligence and statistic inference in codified knowledge to provide assistance in specialized problem solutions, suggesting or recommending actions¹⁷. The knowledge representation for knowledge-driven clinical DSS can be based on rules, clinical guidelines or semantic networks.²⁴ CARDSS (“Cardiac Rehabilitation Decision Support System”)¹⁴ and EXPERT (“Exercise Prescription in Everyday Practice and Rehabilitative Training”)¹⁵ are two DSS developed to provide recommendations for CR professionals. Both are clinical guideline-based, recommending actions based on a predetermined set of options from the guidelines²⁴ of their nationality. Both are also developed for use in computers, distancing the decision support of the place and moment of the decision-making process^{14, 15}.

The basis of evidence-based practice is the combination of the conscious and judicious use of the best scientific evidence available with the clinical experience, taking into account the values and preferences of the patients to decision-making in clinical practice.²⁵ Its noticeable an inherent uncertainty and conditionality in the clinical practice decisions, as scientific evidence is in constant evolution and each patient has its own values and preferences. As the clinical experience increases, beliefs are strengthened and the uncertainties are reduced.¹⁶ Even though, there will ever be some degree of uncertainty in the clinical decision-making.¹⁶ Thus, knowledge representations that embody the uncertainty and causality, such as probabilistic networks, are considered adequate methods of knowledge representation for clinical DSS.²⁶ Influence diagrams (ID) are generalizations of a Bayesian network that include decision variables and utility functions, following the classic decision theory to formalize a decision-making problem.²⁷

Recently, our research group described the development of the firsts two ID to support clinical decision-making in outpatient CR.¹⁶ The ID structure was modelled by experts considering variables listed in scientific literature, consensus, guidelines, and norms of CR.^{8, 28-31} The variables probabilities were obtained in a cohort of patients from a CR referral center of Porto Alegre and the recommendations were validated by CR experts using a different database of patients referred to the same center to select random cases and compare the expert decision with the ID. Both ID were validated and considered representatives of the rationale of clinical practice in CR. However, they were also considered complexes to be used solely in clinical practice.¹⁶ Thus, we decided to develop a software to make these ID available as a clinical DSS. The objective of this study is to describe the conception, development methodology and design of this software, from the idealization and requirement elicitation to architecture and interface design.

Methods

This is a methodological study approved by the Research Committee (ComPesq) of the Federal University of Health Sciences of Porto Alegre (“Universidade Federal de Ciências da Saúde de Porto Alegre” – UFCSPA) under the number 042/2016.

The DSS conception initiated with the formal representation of knowledge in two ID, to help two different moments in the CR. This process was previously described by our research group.¹⁶ The first ID (ID-1) was modelled to help clinicians and other professionals involved in CR to decide about the patients’ admission in the program, and the second ID (ID-2) was modelled to help the professionals involved in the exercise prescription (physiotherapists and exercise therapists) to decide which interventions fit better the patients characteristics, including the targeted metabolic route (aerobic or anaerobic), use of bicycle-ergometer or treadmill for the aerobic training, and addition of localized muscle training, functional electrical stimulation and inspiratory muscle training.¹⁶

The development of CardioDSS is following the Scrum, a “framework for developing, delivering and sustaining complex products”.³² Scrum follows the principles of Agile methods, based on incremental and iterative development.³³ Basically, the Scrum initiates with the definition of the system with requirement analysis and the build of a “*backlog*” – a list of all functionalities, functions, and requirements of the system – that is organized by priorities. With the main backlog defined, the team will set the “sprints” that is the core of Scrum, a time-box of no more than a one-month horizon with a defined goal in the development of the system. The development process is transparent and is monitored by a board containing the product backlog items planned, in progress, finalized and the bugs identified.^{32, 34} This methodology permits the modification of requirements and reorganization of priorities at any time, maintaining the clinical experts involved in all the development process.

Requirement specification, as well as the use case analysis of the DSS, were defined by the domain experts (two physical therapists with experience in CR) and the programmers in early sprints. Functional requirements represent functions or services that the system must be able of execute and non-functional requirements represent

restrictions of functions of the system or quality attributes such as security, precision and performance.³⁵ The requirements specification can be divided into four main steps including the elicitation, analysis, documentation, and validation of the requirements, defining the priorities for the system.³⁶ The elicitation and analysis of the functional requirements were done considering the opinion of the research group composed by more than 10 physical therapists with experience in CR, using a non-structured and open interview approach by the two responsible domain experts, discussing the most important and potentially useful functionalities of the system.

The requirement specification in Scrum framework is an iterative process, allowing the addition of new requirements, even later in the development process.³³ Even though, the requirements presented in this study suffered no changes for at least four sprints, and were reviewed by the research group and are now guiding the implementation of the system. The use case diagram was developed using the free-software for modeling in Unified Modeling Language (UML) Astah Community (Change Vision, Inc. Tokyo, JP). The definitions for all variables were developed by the domain experts, using as sources the scientific literature, guidelines, official websites of cardiology societies. When a definition could not be identified in these sources, medical dictionaries or encyclopedias definitions were used, being validated by the domain experts.

The architecture and interface design were defined in later sprints and were presented and approved by the research team involved in the requirement specification. For the interface design, we defined a color palette for the system using the service of *Paletton 1.01*, a free web-based application for color palette definition. All illustrations for the software and the interface design were developed in CorelDRAW® Graphics Suite X8 using a free-trial license (Corel Corporation; Ottawa, ON).

Results

CardioDSS general description

The CardioDSS will be a knowledge-driven DSS that use as its knowledge base the two previously developed and validated ID¹⁶. It will support two main decisions in the CR, the definition of the patients' admission and the exercise prescription. The targeted users of the software are professionals acting in CR. Although, the software will have a simplified language and include descriptions of the variables of the ID to help less experienced professionals and students to use and learn about CR with the software.

Requirement analysis

Before the requirement elicitation, we defined the main characteristics and functionalities that the system should provide. First, the CardioDSS will be available for Android mobile devices. It must permit the user account management (account creation and exclusion); and patients records management (creation of patients records, search, edition, and exclusion), with the data recording locally and in a backup. It must provide the recommendations for a patient, or without vinculum with a patient. To provide the

recommendations, it will consider the evidence (the variables state definitions) informed by the user, propagate the evidence in the ID and display the results as a graphic, permitting the exportation of the results to a portable document file. It should also permit the user to verify additional information about the variables, and allow a feedback from the user to the development team.

The requirements specified for CardioDSS are presented in the table 1.

Table 1. Requirement specification of CardioDSS

Identifier	Name	Description
Functional Requirements		
FR01	User account creation	For all new user, the system must request a user registration, with a unique username, a valid e-mail account, and a personal password. After the download of the application, the registration activity will be the first and no other function will be allowed without a valid account.
FR02	User account exclusion	The system must permit the exclusion of a user account, removing all data stored about the user and the backup records from the servers.
FR03	User login	All users must be able to connect to the system using a username and password. The system will keep the user connected even when the application is closed.
FR04	User logout	All users must be able to disconnect their account at any moment. The disconnection button will be in the home activity.
FR05	Recover password	The system must allow the recovery of a forgotten password, using the e-mail address provided by the user for validation.
FR06	Patient registration	The system will allow the creation of patient records, with automatic generation of an identifier number and will provide boxes for pre-determined information options including name, birth date (with automatic age calculation by the device date), weight, height and a box of observations, where the user can include any information considered pertinent.
FR07	Edit patients information	The users will be allowed to edit all information included for a patient except the identifier number.
FR08	Patient search	The system must provide an easy search-box for the retrieval of patient records, using the patient identifier number or name.

FR09	Choice of decision support	The system will permit the choice of which influence diagram will be used, meaning, the different decision supports.
FR10	Access to variables information	All variables of the influence diagrams will have an info button with a description of the clinical meaning of the variable.
FR11	Access bibliography of the variable information	All definitions of variables have one or more bibliographic reference that will be presented in a list for each influence diagram, with sequential numbers in the order of appearance in the variables.
FR12	Insert evidence for a patient	The user must be able to choose between the variables of the influence diagrams, defining a state for any number of the variables available. The system will store the evidence provided (variables states) with the patient register for later consultations or editions.
FR13	Change evidence for a patient	The user must be able to change the state of a variable previously defined for a patient. It includes changes during the evidence insertion process and of previous assessments.
FR14	Remove evidence for a patient	The user must be able to remove states of variables previously defined. It includes removal during the evidence insertion process and of previous assessments.
FR15	Verify the recommendations for a patient	The system must use the evidence provided by the user to recalculate the conditional probabilities of the influence diagrams and provide a recommendation in the format of a graphic. With the recommendation, the system will list all evidence inserted so the user can review the choices and their impact on the recommendation. The result will be presented separately for each influence diagram.
FR16	Export results of a patient	The system must allow the exportation of the recommendations with the patient information's into a portable document file type, following a structured pattern.
FR17	Insert evidence without a patient	Similar to FR12, with the difference that the evidence will not be attached to a patient record and will be no data stored.

FR18	Change evidence without a patient	Similar to FR13 but includes only changes during the assessment.
FR19	Remove evidence without a patient	Similar to FR14 but includes only changes during the assessment.
FR20	Verify the recommendations without a patient	Similar to FR15, however, the results will not include any patient information's.
FR21	Export results without a patient	Similar to FR16, however, as will be a structured pattern for document exportation, the spaces were the information of the patient would be included will be empty.
FR22	Learn about the system	The system must provide a section of information about the system and contain how to use the system and how is the calculation of the recommendations (information about probabilistic networks).
FR23	Feedback	The system will contain a box where the user can give a feedback, critics or suggestions for the developer team.
Non-functional Requirements		
NFR01	Operational System	The system will be available for devices with Android Version 8.1 (Oreo) or superior.
NFR02	Responsible design	The system will be available only for mobile applications with all features designed as touch-responsible in the screen, with exception of the "return" button that may be off the screen in some devices.
NFR03	Network protocol	The system must connect with the network by high capacity protocols (WiFi, UMTS or LTE).

NFR04	Network protocol transitions	In cases of transitions between network protocols, the system will maintain the interface workflow, but operations requiring contact with the server may be delayed (including data storage and evidence propagation).
NFR05	Screen resolution and size adaptability	The user interface will have adaptability of screen sizes. Only vector images with at least 300 DPI will be included in the system. The system will be available to be used only in portrait mode. The font size will be adaptive to the size of the screen, so it can remain readable.
NFR06	Availability	The system must be available 24 hours a day and 7 days a week, except for server maintenance period or natural disasters.
NFR07	User authentication	All functionalities of the system will only be available for users registered with a username and password. The password will be recorded with the cryptography algorithm SHA-3. The system will maintain the user connected in the device until he disconnects his account from the device. Every time that the devices be disconnected from the network, it will ask for a new login.
NFR08	Data Storage	The patient data will be stored in an encrypted database inside the device's memory, and a backup for each user account will be stored in an encrypted database in a web server.
NFR09	Open Access	The system and will be available for download at Google Play Store, for free, following the Google Play Store terms and conditions.
NFR10	Interoperability	The user register and authentication will be integrated with a web server. Also, another server will host the API for evidence propagation in the influence diagrams.
NFR11	Rapid evidence propagation	In ideal conditions (stable access to the internet and active server), the system must provide the results of the evidence propagation at the minimum time possible, with an acceptable variation of 10-40 seconds.

API: Application Program Interface; DPI: Dots Per Inch; FR: Functional requirement; LTE: Long Term Evolution; NFR: Non-functional requirement; SHA-3: Secure Hash Algorithm version 3; UMTS: Universal Mobile Telecommunication System.

Use cases analysis

The use case analysis was represented in a use case diagram. The actor represents both the external user and the system, both interacting with all use cases. All individuals that create a valid account will have access to the same use cases. [Insert figure 1]

Variables definitions

All variables of the ID-1 and ID-2 that the user will be able to define a state were defined. All definitions are presented in table 2.

Table 2. Variable definitions

Variable	Influence Diagram	Definition
Referral	ID-1	The patient was indicated for CR by a clinician?
Ischemic cardiopathy	ID-1	Conditions with reduced blood flow to myocardium.³⁷ It includes: - <i>Coronary Artery Disease</i>: a disease characterized by fat substance deposits that leads to a plaque formation inside the walls of a coronary artery, narrowing the lumen of the artery;³⁸ - <i>Silent myocardial ischemia</i>: objective documentation of myocardial ischemia [ex. in an electrocardiogram], in the absence of angina or anginous equivalents;³⁹ - <i>Stable angina</i>: pain or discomfort in the chest due to reduced oxygen supply to the heart (usually in mild Coronary Artery Disease) in specific situations such as physical efforts. The characteristics of stable angina include generally non-prolonged episodes of pain, with similar intensity between them that relieves through rest or medication. If the pain happens more frequently, more intensely, or has a longer duration, it is recommended an investigation to verify if the condition has not progressed to unstable angina.⁴⁰ Angina can be classified into 4 classes according to the Canadian Cardiovascular Society: Class I [vigorous effort only], Class II [with moderate effort], Class III [with minimum effort], and Class IV [at resting].⁴¹ - <i>Post-Acute Myocardial Infarction</i>: A myocardial infarction occurs with the rupture of an atherosclerotic plaque and the formation of a thrombus that get deposited in one of the coronary arteries obstructing the passage of blood. The lack of blood supply leads to myocardial ischemia, which, in a prolonged situation, can lead to the death of the cells of the cardiac muscle region supplied by the blocked artery. The acute treatment involves the use of thrombolytic medications or surgical procedures such as angioplasty and myocardial revascularization. After a non-fatal myocardial infarction, the affected region goes through a healing process, which lasts around 8 weeks. This healed region does not exhibit the same

		capacity of contraction as the rest of the heart and the location and extent of the injury may impact on the quality of blood pumping from the heart to the body.⁴⁰ - <i>Post-angioplasty or myocardial revascularization:</i> Angioplasty (also known as Percutaneous Coronary Intervention) is a minimally invasive procedure for clearing a coronary artery. It is performed using a special tube with a cuff that is inflated to create an opening in the arterial obstruction, with possible placement of a stent (tubular net used to maintain the opening of the artery after angioplasty). Myocardial revascularization surgery is an open surgical procedure [usually with an incision on the sternum] that uses arteries from other parts of the body as "bridges" to redirect blood flow around the coronary blockage, reestablishing the blood flow to the cardiac region affected by the arterial obstruction.⁴²
Reduced muscle endurance	ID-1	Muscle endurance is the capacity to maintain a prolonged static or dynamic effort without affecting the quality of exercise. ⁴³ The muscle endurance is reduced when the muscle develops early fatigue compared to individuals with the same clinical conditions and/or compared with a prior evaluation of the same individual.
Reduced muscle strength	ID-1	Muscle strength can be defined as the amount of tension that a muscle (or a muscle group) can generate within a specific movement pattern and certain speed of movement. ⁴³ Muscle strength is reduced when the amount of muscle tension generated is less than expected for an individual under the same clinical conditions and/or less than a previous evaluation of the same subject.
Abnormal exercise stress test	ID-1	A noninvasive test with incremental effort (usually on a treadmill), while the cardiovascular function (heart rate, respiratory rate, electrocardiogram, systemic arterial pressure) and subjective sensation of exertion are monitored. The test helps in the diagnosing of Coronary Artery Disease or another possible cause for angina. It is also used to determine the level of safe exercise. Abnormalities in exercise testing may include early fatigue, angina, electrocardiogram alterations, elevation or reduction in systemic blood pressure. ⁴⁴
Risk factors for Coronary Artery Disease	ID-1	There are some recognized risk factors for Chronic Artery Disease, including:

		- <i>Systemic Arterial Hypertension</i>: sustained elevation of blood pressure levels ≥ 140 (systolic) and/or 90 mmHg (diastolic), according to the Brazilian Society of Hypertension⁴⁵ or elevation of systolic pressure ≥ 130 or diastolic ≥ 80 according to American Heart Association;⁴⁶ - <i>Diabetes</i>: a metabolic disorder characterized by hyperglycemia (persistent fasting blood glucose levels at harmful levels (≥ 126 mg / dL), due to a deficiency in insulin production and/or its action;⁴⁷ - <i>Smoking</i>: mental and behavioral disorder due to use of tabaco;⁴⁸ - <i>Dyslipidemia</i> (plasma level of lipoproteins (triglycerides, high-density lipoprotein (HDL) or low-density lipoprotein (LDL) may be elevated (hyperlipidemia), or reduced (hypolipidemia).⁴⁹
Decompensated diabetes mellitus	ID-1	Persistent elevation of the blood glucose while fasting at harmful levels (≥ 126 mg/dL) despite optimized treatment. ⁴⁷
Other decompensated metabolic problems.	ID-1	Any disorder that involves changes in the metabolism of carbohydrates, lipids, proteins, water or nucleic acids, ⁵⁰ which results in loss of metabolic control of homeostasis in the body. ⁵¹ For example, obesity, changes in blood pH (alkalosis or acidosis), hormonal changes (such as hypo or hyperthyroidism), dehydration, hyperuricemia (elevated concentrations of uric acid in the blood), changes in temperature (hypothermia or hyperthermia), decompensated dyslipidemias.
Acute systemic infections	ID-1	Infection (invasion and multiplication of microorganisms in the body tissues) of sudden or recent onset, with distribution in the whole body rather than concentrated in a specific area (organ, tissue). ⁵²
Thrombophlebitis	ID-1	Inflammation of a vein (phlebitis) with the formation of a thrombus inside the vein (thrombosis) at the site of inflammation. ⁵³
Recent embolism	ID-1	Obstruction of a vessel, often an artery, by migration of a foreign body (said embolus) carried by the bloodstream. ⁵⁴

Serious orthopedic or neurological problems	ID-1	Serious orthopedic (related to skeletal system and muscles, joints and ligaments) ⁵⁵ or neurological (related to the nervous system [central, peripheral and autonomic], and neuromuscular junction) ⁵⁶ systems disorders or diseases.
Acute systemic disease or fever with unknown origin	ID-1	A disease that affects the whole body, generalized, ⁵⁷ or elevation of body temperature to a temperature above 37.8 °C with an unspecified origin. ⁵⁸
Third degree atrioventricular block (without pacemaker)	ID-1	Complete atrioventricular block (complete interruption of atrioventricular conduction, causing electrical disconnection between atria and ventricles), ⁵⁹ without correction with a cardiac pacemaker.
Severe mitral or aortic valve disease without adequate treatment	ID-1	Presence of severe insufficiency (blood regurgitation due to valve incompetence) or stenosis (obstruction of blood output by calcification of valvular structures, associated or not with the fusion of valvular leaflets) of the mitral valve (between the atrium and the left ventricle) or aortic valve (between left ventricle and aortic artery), classified through diagnostic exams and functional assessments, without optimized treatment. ⁶⁰
Stable angina grade IV and unstable	ID-1	Stable angina grade IV (chest pain or discomfort due to insufficient oxygen supply to the heart while resting) ⁴⁰ or unstable angina (also referred to as Acute Coronary Syndrome. It is an emergency situation caused by a severe reduction of blood flow to the myocardium. Causes unexpected chest pain, usually occurring at rest, may last longer than stable angina, usually does not improve with rest and medications, may worsen over time, and may be related to an infarction acute myocardial infarction). ⁶¹
Uncontrolled arrhythmia	ID-1	Alteration of the frequency, formation and/or electrical impulse conduction through the myocardium, without optimized treatment. ⁵⁹
Decompensated Heart Failure	ID-1	A clinical syndrome in which a structural or functional alteration in the heart leads to its inability to eject and/or accommodate blood within physiological pressure values, causing functional limitation and requiring immediate therapeutic intervention. Decompensated Heart

		Failure may be acute (recent onset), really decompensated (with the instability of a chronic condition), or refractory, persistent. ⁶²
Electrocardiogram with ST segment depression > 2mm	ID-1	Depression of the ST-segment (ECG portion between the QRS complex and the T wave) compared to the baseline defined by the PR-segment, indicative of myocardial ischemia [24]. Depression > 2mm is considered a high-risk factor for cardiovascular events during exercise by the American Association of Cardiovascular and Pulmonary Rehabilitation. ⁹
Pericarditis or acute myocarditis	ID-1	Acute inflammation of the pericardium (saccular formation involving the heart and roots of large vessels) ⁶³ or of the myocardium (cardiac muscle), it is possible that both of them may be of infectious origin or non-infectious. ⁶⁴
Uncontrolled arterial hypertension	ID-1	High systolic blood pressure ≥ 200 mmHg or diastolic ≥ 110 mmHg. ⁶
Mental disorder therapy-dependent	ID-1	Health condition with psychological, mood or behavioral affection that causes discomfort and hinders the functionality of the individual ⁶⁵ dependent on drug therapy.
Diabetic retinopathy with retinal displacement	ID-1/ID-2	Diabetic retinopathy is a neurovascular complication of diabetes mellitus, with deposition of abnormal material on the walls of the retinal blood vessels, with the formation of microaneurysms that can cause ruptures and bleeding. With progression, there is a formation of new abnormal vessels, more fragile to ruptures and bleeding. The scar tissue can contract and cause retinal displacement and potentially blindness. ⁶⁶
Peripheral artery disease degree II - limiting, III and IV	ID-1/ID-2	A condition that affects non-cardiac and non-cranial arteries, leading to peripheral artery obstruction, with reduced perfusion in the corresponding area. ⁶⁷ When the obstruction occurs in the lower limbs, it is characterized primarily by intermittent claudication resulting from lack of blood supply. According to Fontaine's classification, it varies from stage I (asymptomatic), IIa (limiting intermittent claudication), IIb (disabling intermittent claudication), III (resting ischemic pain) to stage IV (arterial ulcer or gangrene). ⁶⁸

Severe untreated pulmonary or arterial hypertension	ID-1	Pulmonary hypertension: diagnosed when the average pulmonary arterial pressure is > 25mmHg at rest (measured by right heart catheterization).⁶⁹ Severe arterial hypertension: sustained elevation of systolic blood pressure $\geq$ 180mmHg and/or diastolic $\geq$ 110mmHg, according to the Brazilian Society of Cardiology [10]. Is considered a hypertensive crisis requiring immediate consultation by the American Heart Association.⁴⁶
Anemia	ID-1	Defined as hemoglobin (Hb) values in the blood below normal for age and gender. ⁷⁰
Moderate neuromuscular, musculoskeletal and osteoarticular disorders	ID-1/ID-2	Moderate neuromuscular disorders (disorders characterized by primary involvement of the motor unit - composed by the medullar motoneuron, nerve root, peripheral nerve, neuromuscular junction and muscle), ⁷¹ including muscular dystrophies, myopathies, motor neuron diseases, diseases of ion channels, mitochondrial diseases, neuromuscular junction diseases and peripheral nerve diseases) ⁷² or other affections in the skeletal system, muscles, joints and ligaments of moderate intensity.
Ventricular tachycardia at rest	ID-1	Heart rate greater than 100 beats per minute when assessed at rest. ⁵⁹
Ventricular aneurysm	ID-1	Localized dilation or saccular protrusion in the wall of a ventricle, occurring most frequently after a myocardial infarction. ⁷³ It is presented as a well delineated, scarred or fibrotic myocardium area, devoid of muscle or containing necrotic, dyskinetic or akinetic (with abnormal or no movement) systolic muscle contraction. ⁷⁴
Moderate aortic stenosis	ID-1	Obstruction of the left ventricular outflow tract by calcification of the valvular structures, associated or not with the fusion of the valves of the aortic valve. Aortic stenosis is classified by echography, with bloodstream velocity between the left ventricle and the aorta of 3 to 4 m/s, with an average pressure gradient of 25 to 40 mmHg and a valve area of 0.8 to 1.5 cm ² . ⁶⁰
Thoracic or abdominal aortic aneurysm	ID-1	Localized or diffuse dilatation in an artery with a diameter of at least 50% larger than the normal artery size. Aneurysms in the aortic artery can occur anywhere along its length and may include its ascending, descending, or abdominal thoracic portion. ⁷⁵

Ventricular extrasystoles class II, III, and Lown IV	ID-1	Ventricular extrasystoles (also called premature ventricular beats) present as an early-onset ventricular beat with a post-extrasystolic pause in the electrocardiogram. ⁵⁹ The Lown classification applies to the occurrence of ventricular extrasystole after myocardial infarction and ischemia, graduating the extrasystole to 0 (without extrasystole), 1 (isolated ventricular extrasystoles, occasional), 2 (frequent ventricular extrasystole (> 1 / minute or 30 / hour)), 3 (polymorphic ventricular extrasystoles), 4 (a- couplets (two consecutive) ventricular extrasystole; b- repetitive ventricular extrasystoles (3 or more), 5 (ventricular extrasystole at the beginning of the cycle - "R on T phenomenon"). ⁷⁶
Acute myocardial infarction (<8 weeks)	ID-1	A myocardial infarction occurs with the rupture of an atherosclerotic plaque and the formation of a thrombus that get deposited in one of the coronary arteries obstructing the passage of blood. The lack of blood supply leads to myocardial ischemia, which, in a prolonged situation, can lead to the death of the cells of the cardiac muscle region supplied by the blocked artery. The acute treatment involves the use of thrombolytic medications or surgical procedures such as angioplasty and myocardial revascularization. After a non-fatal myocardial infarction, the affected region goes through a healing process, which lasts around 8 weeks. This healed region does not exhibit the same capacity of contraction as the rest of the heart and the location and extent of the injury may impact on the quality of blood pumping from the heart to the body. ⁴²
Moderate respiratory insufficiency	ID-1/ID-2	A clinical condition in which the respiratory system cannot maintain the values of arterial oxygen pressure (PaO ₂) and/or arterial carbon dioxide pressure (PaCO ₂) within normal limits (PaO ₂ > 60mmHg and PaCO ₂ <50mmHg) for a given metabolic demand. As these gas pressures are influenced by the fraction of inspired oxygen (FiO ₂) – which at sea level is 21% – , the respiratory insufficiency can be graded according to the relationship between PaO ₂ and FiO ₂ , with values >400mmHg are indicative of normal oxygenation, 300 to 400 mm Hg oxygenation deficit, <300 mm Hg respiratory insufficiency and <200 mm Hg severe respiratory failure. ⁷⁷
Untreated left coronary trunk lesion or equivalent	ID-1	The left coronary trunk refers to the proximal segment of the left coronary artery arising from the left aortic sinus just below the sino-tubular junction until its bifurcation in left anterior

		descending arteries and left circumflex arteries. The left coronary trunk is responsible for supplying about 75-100% of the left ventricular cardiac mass. Atherosclerotic lesions in this portion of the left coronary artery will reduce the flow of a large portion of the myocardium, at high risk for potentially fatal cardiovascular events or left ventricular dysfunctions and arrhythmias.⁷⁸
Hypertrophic Cardiomyopathy	ID-1	Cardiovascular disease of genetic origin, characterized by left ventricular hypertrophy without dilation of associated ventricular chambers and in the absence of any other cardiac or systemic disease that could be able to produce the cardiac hypertrophy verified in the patient.⁷⁹
Acute cardiomegaly	ID-1	Cardiomegaly is the term referring to the increase in cardiac volume, with a cardiothoracic index (ratio between maximum transverse cardiac diameter and thoracic cavity diameter in maximal inspiration, evaluated by chest radiography) above 0.5. Acute cardiomegaly is when the cardiothoracic index is higher than 0.55.⁸⁰
Obesity class II or III	ID-2	A condition in which the percentage of body fat is increased to an extent where health and well-being are compromised. The World Health Organization classifies the obesity by the body mass index (BMI = weight / height x height) as normal (18.5-24.99), pre-obesity (25-29.99), obesity class I (30-34.99), class II (35-39.99) and class III (≥ 40).⁸¹
Syncope	ID-2	Complete, transient and abrupt loss of consciousness associated with the inability to maintain postural tonus, with fast and spontaneous recovery. The presumed mechanism is cerebral hypoperfusion. There should be no clinical features of other non-syncopal causes of loss of consciousness such as convulsion, previous traumatic brain injury or just apparent loss of consciousness (pseudo-syncope).⁸²
Important Claudication	ID-2	Change in gait with weight-bearing failure while walking, also described as "limp", with sufficient frequency that requires interruption of walking. It may be related to muscle pain, joint pain or lack of perfusion, with intermittent claudication being the most evident characteristic of peripheral arterial disease of the lower limbs.⁹

Neurological or orthopedic limitation	ID-2	Orthopedic (linked to the skeletal system and muscles, joints and ligaments) ⁵⁵ or neurological (related to the nervous system [central, peripheral and autonomic], as well as neuromuscular junction) ⁵⁶ disorders or diseases that cause functional limitation.
Systemic arterial hypotension	ID-2	Blood pressure is considered normal with systolic blood pressure values ≤ 120 mmHg and diastolic blood pressure ≤ 80 mmHg. There is no defined limit for sustained hypotension, being diagnosed when low blood pressure measures are associated with the presence of symptoms such as dizziness, nausea, syncope, blurred vision and others. ⁸³
Significant arthropathies that compromise the ability to walk	ID-2	Pathology or disorder in joints that compromise the ability to walk independently. It may be associated with acute inflammation, as well as progressive degeneration of the joint. ⁸⁴
Pain in lower limbs	ID-2	Pain localized in the lower limbs that may affect the ability to walk independently or to produce strength.
Contraindications for localized muscular resistance	ID-2	Resisted exercises should be indicated for patients after a minimum of 5 weeks from an infarction, with aerobic exercise in a rehabilitation program for at least 4 weeks or a minimum of 3 weeks since the percutaneous intervention with aerobic exercise for 2 or more weeks. Situations that need caution due to lack of evidence of resistance training: uncontrolled arrhythmias, severe valvulopathies, uncontrolled hypertension and moderate arterial hypertension (systolic pressure > 160 or diastolic > 100 mmHg), and congestive heart failure. ⁸⁵
Arthropathy of upper limbs	ID-2	Inflammatory and/or degenerative joint disease affecting upper limb joints. ⁸⁴
Pain in the chest	ID-2	Pain in the thoracic region regardless of origin, anginal, musculoskeletal or other.
Recent sternotomy	ID-2	Median sternotomy is a medial vertical incision between the sternal groove and the top of the xiphoid process, separating the sternum completely. It is considered the gold standard incision for open cardiac procedures, with a low incidence of failure and optimal long-term proven

		outcomes. ⁸⁶ Usually, after revascularization surgery, patients require a rest period of 2-6 weeks for recovery of the procedure. ⁸⁷
Arteriovenous Fistula in Upper Limb	ID-2	A connection between an artery and a vein, surgically performed with the intention of making the vein thicker and stronger, so that punctures with hemodialysis needles can occur without complications. ⁸⁸
Upper limb pain	ID-2	Pain in upper limb regardless of origin, musculoskeletal, vascular, neurological, orthopedic.
Elderly (aged 70+)	ID-2	Elderly with more than 70 years-old.
Respiratory Muscle Weakness	ID-2	Maximal inspiratory pressure assessed by manovacuometry <70% of predicted ⁸⁹ or <60cmH ₂ O. ⁹⁰
Working heart rate	ID-2	One of the ways to prescribe and control the intensity of training during cardiac rehabilitation is by controlling the heart rate. Generally considering ranges of maximum heart rate or reserve heart rate (the difference between maximum heart rate and heart rate at rest) evaluated in an exercise test prior to initiation of cardiac rehabilitation. ⁹ This variable considers prescription through reserve heart rate.

ID-1: first influence diagram that support decision of admission of the patient in a CR program. ID-2: second influence diagram that support decision of intervention options in admitted patients.

Architecture design

The user will interact with the system by an Android mobile device containing the graphic user interface. The mobile device will also contain a local database that is the main storage of the patients' records and recommendations historic of the ID-1 and ID-2. The application will communicate with two servers.

The first, named “data server”, is the one that realizes the login and logout authentication and stores the users account information's and the backup of their registered patients and recommendations of the ID, protected with a cryptography algorithm. The chosen server platform for the “data server” was the Back4App (Back4App, Inc. Sunnyvale, CA), a free parse server platform that is hosted by AWS (Amazon Web Services, Inc. Seattle, WA).

The second server is the “application server” that is hosted in a private computer of the developer team, containing the inference algorithm that calculates the propagation of the evidence in the ID chosen by the user. The influence algorithm will be implemented with the open-code API (Application Program Interface) from UNBBayes (University of Brasília – UnB; Brasília, DF), a Java-based for modeling, learning and reasoning on probabilistic networks.⁹¹

The application server will receive the evidence inserted in the mobile application and calculate the results of the selected ID. The results will return to the mobile device to be presented to the user and will also be sent to the “data server” to be stored. The high-level structures of the system were designed and are represented in figure 2. [Insert figure 2]

Graphic user interface design

The graphic user interface design was developed to respect the use cases and requirement analysis previously described. In figure 3 are presented the main screens models, for the principal functionalities.

The login and user registration functionalities will be available on the screen A. The screen B represents the home screen, where the user will be able to access the main functionalities of the system (add new patient, access patient records, access information about the software, access fast recommendations without vinculum to a patient, send a feedback and logout from the system). The screen C represents an access for the user to the development history of CardioDSS and information about how the recommendations are generated, with explanations about Bayesian inference and ID. The screen D is the screen for registration of a new patient, where the user can insert some pre-defined information, but also include any additional information considered relevant.

The screen E is the screen where the user can choose the decision support he wants if it is for admission of a patient in a CR program (ID-1) or definition of the interventions during the CR (ID-2). The screen F represents the screen where the user will inform the states of the variables that he knows, i.e. insert evidence. The screen G represent how the variables definition will be available and will present a button to the access of the reference list screen (not represented in the figure). The screen H shows

the result of the first decision support, in a graphic that represents the utility calculated by the evidence propagation in the ID, varying from -100 to +100 (representing, respectively a “no” and a “yes” recommendation). In this screen, the informed evidence will be recorded and it will permit the export of the result to a portable document file and will provide an easy access to the next decision support.

The screens I and J are similar to screen F and G but present the variables to the second decision support. The screen K is the screen of the access to the patients' records, providing an ease search box and access to add a new patient. The screen L represent the patient record, where the user will be able to edit the record, save the alterations, verify previous recommendations and add new decision supports with changes in the evidence to be propagated. The fast recommendation screen flow was not presented in the figure, but it will be very similar to the screen flow between the screens E and J, but without identification of a patient and the recommendations will not be recorded. [Insert figure 3]

Discussion

In this study, the concept, definition of requirements and use cases, development methodology, and architectural and Graphic User Interface design of CardioDSS, a knowledge-driven, mobile-based DSS to assist the decision-making in supervised outpatient CR has been detailed. This study can help the future users of the system to understand how it was conceived and designed and help other research groups in the planning of different clinical DSS.

We identified two DSS for CR professionals previously developed. CARDSS is a record system with DSS functionalities focused on the patient assessment for CR indication and to increase the guidelines adherence during the CR process, providing recommendations based on a knowledge representation of the Dutch guideline for CR.¹⁴ A randomized controlled trial including 31 Dutch CR centers, verified an improvement in the guideline's conformity about exercise of 3.5%, educative interventions of 23.7% and relaxing therapies of 41.6% with CARDSS use.²⁰ EXPERT was developed by a group of experts in chronic diseases from 11 European countries, with endorsing of the European Association of Preventive Cardiology. The knowledge representation for EXPERT was also based on clinical guidelines and is focused in exercise prescription in CR, including exercise intensity, frequency, duration, type, number of sessions and rehabilitation program duration and extra modalities of exercise indicated.¹⁵

Both CARDSS and EXPERT considers only the information provided by the users to make the recommendations. Our software, by using ID as the knowledge-base, include the uncertainty about all variables without state informed using probabilistic inference for the recommendation,¹⁶ what we consider as a more conservative and closest approach to represent the clinical rationale of decision-making in CR.

A DSS does not replace the health professional judgment, thus, the maintenance of positive results with DSS can be achieved only by the learning improvement through the use of a DSS.⁹² Therefore, we consider that CardioDSS can be useful as an educational tool besides a DSS. By the generation of recommendations based in clinical cases (of the real practice or simulated), the users can perceive the influence of the

evidence provided and the uncertainty about the other variables in the recommendations and learn with that. The inclusion of definitions and references for all variables was considered important to help in the learning process, and incentivize the user curiosity about the different conditions presented in the software and support the reflection over the recommendations provided.

The definition of a structured development methodology helps the team to organize the steps of the development life-cycle and the roles of each individual.⁹³ Agile software development approaches have become more popular and all of them share some common principles: improved customer satisfaction, adapting to change the requirements, frequent delivering working software and team collaboration.⁹⁴ We have chosen the Scrum for CardioDSS development, because it is proposed for small teams organized to optimize flexibility, creativity, and productivity in an iterative, incremental and transparent development process.³² The flexibility of Agile methods does not mean lack of project definition; overall, a high-level project scope is defined upfront and revised in each iteration.⁹⁵

Accordingly with Serna et al. (2017), it's generally accepted by the software development community that the requirement specification, as the product of requirement engineering, is the lifecycle stage with the highest influence on the quality of the final product.⁹⁶ It seeks to understand and capture the stakeholder needs and to identify the information determining what features the software should have⁹⁷ and can be considered as the representation in words of the idealized software. We defined 23 functional requirements and 11 non-functional requirements specifically for CardioDSS. Although requirement specification is an individualized analysis for a specific software, we consider that following developers of mobile DSS can use our analysis as an initial aid in their requirement engineering.

The user interfaces are the operational units of the system, the tangible vector, where all features are made available to users.^{98, 99} The interface style has direct effects on perceived ease of use and usefulness of a system, which can influence the users' intention to use the system, once, from a user's perspective, the system interface represents the system by itself.¹⁰⁰ A "friendly" design allows the user to interact with the system in a natural and intuitive way.⁹⁸ The touchscreen, the now main stream to user's interactions with the system in mobile devices, shortens the distance between the user and interface, enabling the user for a more realistic sensation and enrich the topic in interface usability.¹⁰¹ The CardioDSS graphic user interface was designed to provide a "friendly" usability, with the main functions disposed in the home page and allowing the user to follow a course in the use, for example, after adding a new patient, the user can follow to add decision support, with the two available decision supports options. Considering the two options, the natural flow is to add a decision support for patients' admission in the CR program and later the definition of interventions if the patient was recommended for admission in CR.¹⁶ The system was designed to follow this concept, but also to maintain the user independence to choose between the decisions support available.

In our architecture analysis, we identified three main components that will interact so the CardioDSS can fulfill the requirements elicited. The probabilistic inference calculation in the CardioDSS will use the open-source API from UNBBayes that is Java-based and can propagate the evidence and recalculates the conditional probabilities.⁹¹ Because this API presents dependences with a graphic framework that is

not supported in Android, we decided to use the API through a server. Although the adaptation of the API in a server can execute the evidence propagation, it maybe needs a prolonged time to provide the results that will be displayed in the mobile device and the system may fail to attempt to the non-functional requirement NFR11 (provide the results fast). As a software maintenance stage tends to be endless, it is important to consider the architecture sustainability while designing the software architecture¹⁰² (i.e. the degree to which the software's architecture supports its continued maintenance and evolution over time without requiring substantial and expensive restructuring)¹⁰³. Considering the architectural sustainability of CardioDSS, we pretend to develop a framework to run the evidence propagation in the mobile device, using as the base the open-source code from UNBBayes and to let this framework also open-source.

The CardioDSS is currently being implemented and the first release is planned for December, this year. It will be made available cost-free for download in the Google Play Store (Google Inc. California, US). The ID-1 and ID-2 recommendations were previously validated by experts in the CR field.¹⁶ Even though, we plan to validate the CardioDSS as a DSS for CR, with its implantation in a CR service and assessment of the users' perception of the software and the comparison of the professionals' decisions in clinical practice with or without the use of CardioDSS. We also plan to evaluate CardioDSS as an educational tool, implanting it on academic classes of CR and collecting the perception of professors and students about its use for teaching-learning purposes.

Conclusion

This study provides an overview of the concept, definition of the requirements, use cases, architecture and graphic user interface design of CardioDSS, the first mobile-based knowledge-driven DSS with Bayesian inference to make recommendations for supervised outpatient CR professionals. We believe that our analysis can help the future users of CardioDSS to understand our motivation and how we conceived the software, and also help other research teams that have interest in the development of clinical DSS in different fields.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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Figures

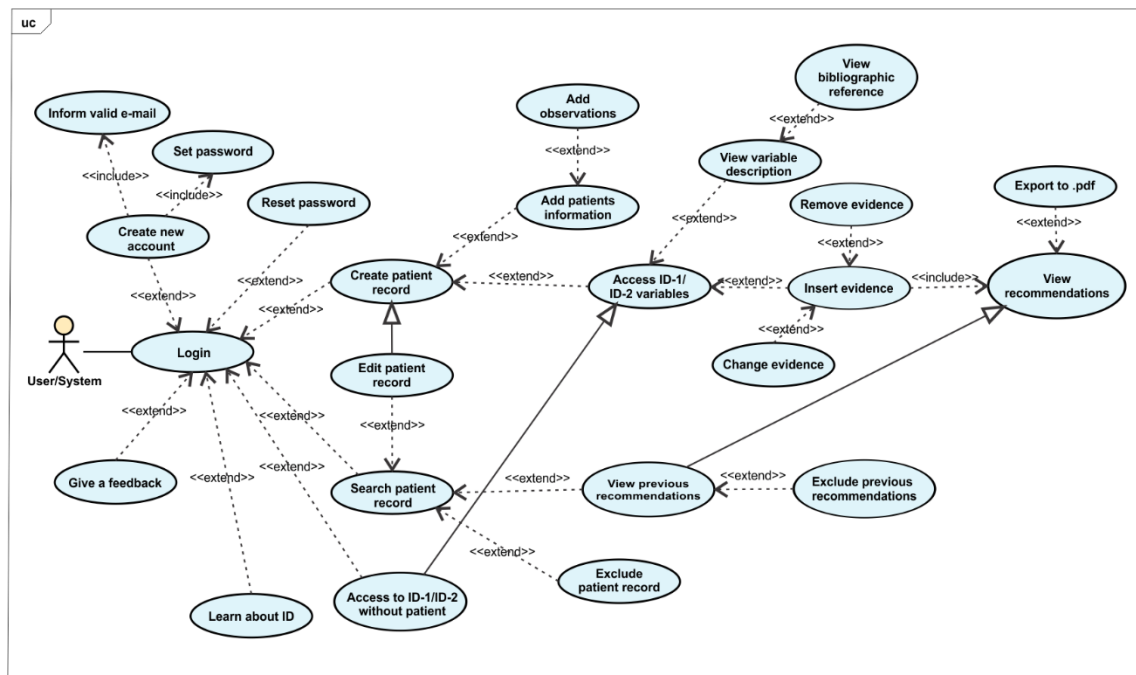


Figure 1. Use case diagram of CardioDSS

ID-1: first influence diagram that support decision of admission of the patient in a CR program. ID-2: second influence diagram that support decision of intervention options in admitted patients. .pdf: Portable document file type. Dotted arrows represent “extend” or “include” relations between cases. Continuous arrows represent generalizations between cases.

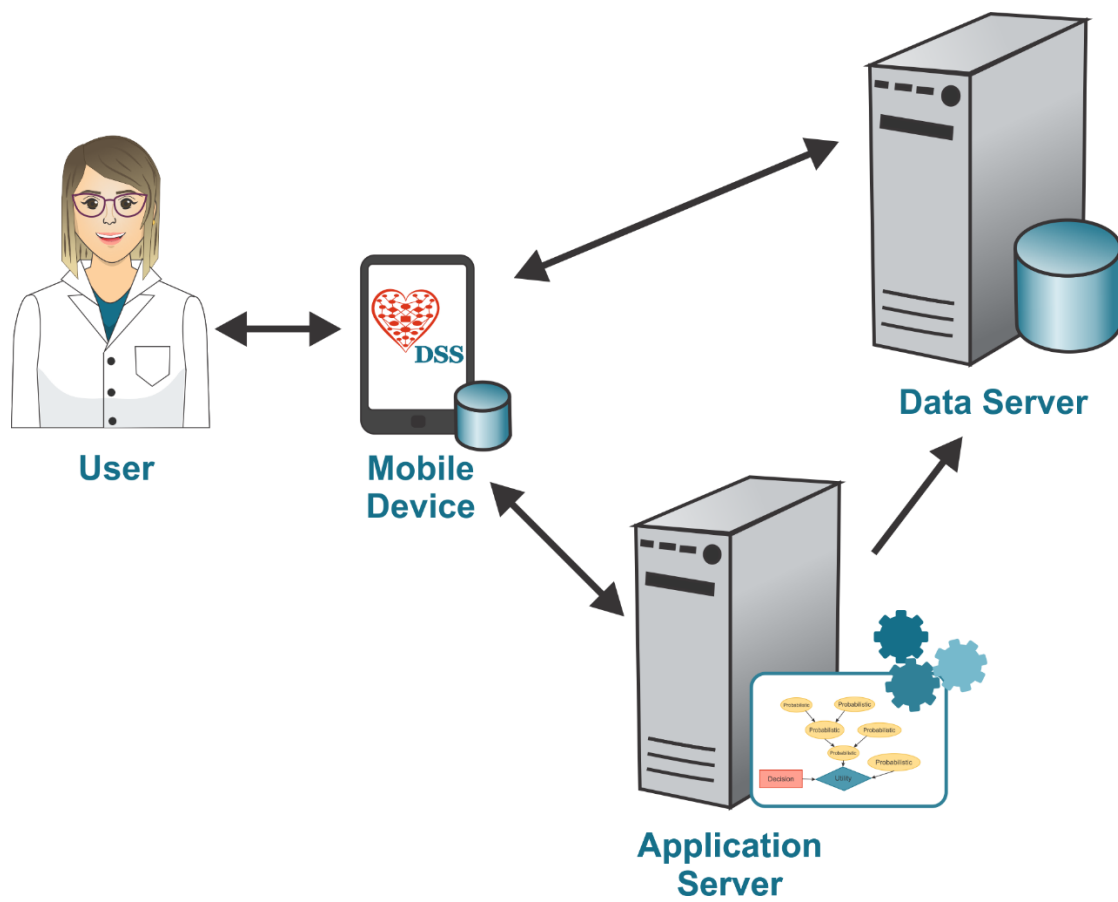


Figure 2. High level components of architecture design of CardioDSS

A



Username _____

Password _____

Login

Forgot my password

New Account

B



New patient



Learn about CardioDSS



My patients



Fast recommendation

Send us a Feedback

Logout

C



Learn about CardioDSS

CardioDSS is a Clinical Decision Support System developed to help Cardiac Rehabilitation (CR) professionals in two decision-making moments, the admission of a patient and the definition of the interventions during the program. It was also developed to serve as an educational software to help professors of academic classes about CR.

It was developed by a research team from the Federal University of Porto Alegre (Universidade Federal de Ciências da Saúde de Porto Alegre - UFCSPA) e colaboradores from the Laureate International Universities.

The knowledge base of CardioDSS are two Influence Diagrams.

A Influence diagram is a generalization of a Bayesian Network that includes decision variables and utility functions, following the

D



New patient

Patient Number: 001 Sex: _____

Name: _____

Birth: _____ Age: _____

Weight: _____ Kg Height: _____ m

Observations:

Add any information considered relevant here.

Add Decision Support

E

Patient 001 - Name _____

Which decision you need to make?

Admission in a Cardiac Rehabilitation Program

Definition of the interventions during the Cardiac Rehabilitation

F

Patient 001 - Name _____

Admission in a Cardiac Rehabilitation Program

Insert evidences

Referral	YES	NO
Ischemic cardiopathy	YES	NO
Exercise stress test with abnormality	YES	NO
Risk Factors for Coronary Artery Disease	YES	NO
Diabetes Mellitus uncontrolled	YES	NO
Other metabolic problems uncontrolled	YES	NO
Acute systemic infections	YES	NO

Propagate Evidences

G

Patient 001 - Name _____

Admission in a Cardiac Rehabilitation Program

Insert evidences

Acute systemic infections

Infections (invasion and multiplication of microorganisms in the body tissues) of sudden or recent onset, with distribution in the whole body rather than concentrated in a specific area (organ, tissue) [17].

<See reference list>

Propagate Evidences

H

Patient 001 - Name _____

Admission in a Cardiac Rehabilitation Program

Recommendation:

No | 65 | Yes

Evidences propagated:

Referral: Yes
Ischemic cardiopathy: Yes
Diabetes Mellitus uncontrolled: No

Export PDF

Add Next Decision Support

I

Patient 001 - Name _____

Definition of the interventions during the Cardiac Rehabilitation

Insert evidences

Diabetic Retinopathy with retine detachment	YES	NO
Obesity (stage III or IV)	YES	NO
Syncope	YES	NO
Intermittent claudication	YES	NO
Pain in lower limbs	YES	NO
Chest Pain	YES	NO
Elderly (aged 70+)	YES	NO

Propagate Evidences

J

Patient 001 - Name _____

Definition of the interventions during the Cardiac Rehabilitation

Recommendation:

No | Yes

Aerobic training equipment:

Trademill	-5	64
Cycle Ergometer		

Additional interventions:

FES	97
Streight Training	75
IMT	-60
Flexibility	99
Targeted Metabolic Route:	
Aerobic	99
Anaerobic	77

Evidences propagated:

Obesity (stage III or IV): Yes
Chest Pain: No
Elderly (aged 70+): Yes
Inspiratory muscle weakness: No

Export PDF

K



My Patients

Search by the patient number or name:

001 - Name _____

002 - Name _____

003 - Name _____

New patient

L

Patient 001 - Name _____

Patient Number: 001 Sex: _____

Name: _____

Birth: _____ Age: _____

Weight: _____ Kg Height: _____ m

Observations:

Add any information considered relevant here.

Save changes

Previous Decision Support:

20/06/18 - Admission

20/06/18 - Intervention

Add Decision Support

Figure 3. Graphic user interface design of CardioDSS.

A. Login screen; B. Home screen; C. Learn about CardioDSS screen; D. New Patient screen; E. Decision support options screen; F. Insert evidence for admission decision support screen; G. Variable definition screen; H. Recommendation result for admission decision support; I. Insert evidence for interventions decision support screen; J. Recommendation result for interventions decision support; K. My patients screen; L. Patient record screen.

7 CONCLUSÃO GERAL

Este trabalho apresenta a concepção do software CardioDSS ("Cardiovascular Rehabilitation Decision Support System"), que será o primeiro SAD em RC a utilizar como base de conhecimento DI, para uso em dispositivos móveis no mundo e o primeiro a ser disponibilizado no Brasil. O CardioDSS, diferentemente dos SAD prévios, leva em consideração a incerteza na formulação de recomendações para dois momentos na prática clínica da RC ambulatorial supervisionada; a decisão quanto à admissão de um paciente em um programa de RC ambulatorial supervisionada e a definição da intervenção a ser conduzida com o paciente que é admitido no programa, incluindo o equipamento para o treinamento aeróbico (bicicleta ou esteira), intervenções associadas e rota metabólica priorizada.

As principais funcionalidades e casos de uso do sistema incluem criação e exclusão de contas de usuários; criação, edição, busca e exclusão de registros de pacientes; disposição para definição de estados para qualquer número de variáveis dos DI; geração de recomendações vinculadas ou não à registros de pacientes, através da propagação dos estados definidos pelos usuários para as variáveis dos DI e permitir a exportação dos resultados.

Foram construídas definições para todas as variáveis dos DI, que estarão disponíveis para consulta no momento da definição dos estados das variáveis. A arquitetura do CardioDSS inclui três componentes que interagem entre si: o dispositivo móvel contendo a interface gráfica do usuário, um servidor para autenticação e armazenamento de dados das contas do usuário e um servidor contendo a API disponibilizada pelo UNBBayes, que calcula a propagação dos estados informados nos DI. O design da interface gráfica do usuário foi desenvolvido considerando a facilidade e agilidade no uso, definindo uma identidade visual para o software, com delimitação de paleta de cores específica e autoria própria de todas as imagens incluídas no software.

Considerando que a necessidade de um servidor para propagação da inferência probabilística esteja mais suscetível a falhas por falta de conexão com a internet, bem como gerar atrasos na recomendação, um dos projetos que estamos iniciando é a adaptação da API existente para torná-la compatível com o sistema operacional Android e deixar este código aberto e documentado, para

possibilitar seu uso no desenvolvimento de outros SAD baseados em redes probabilísticas.

O CardioDSS está atualmente em sua fase de implementação e a sua primeira versão deverá ser disponibilizada ao final deste ano. Está planejada a validação do SAD, através de sua implantação em um serviço de RC e comparação das decisões com e sem o uso do software. Considerando a importância da disseminação de conhecimento sobre RC e o potencial do SAD concebido para estimular a aprendizagem sobre RC, também planeja-se sua avaliação em ambiente educacional, com uso por professores e alunos universitários de classes que abordem RC, verificando se o SAD consegue ser útil no processo de ensino-aprendizagem.

Este estudo será uma fonte importante de informação para os futuros usuários do *software*, que se interessarem sobre sua concepção e formalização dos passos iniciais de seu desenvolvimento, bem como para outros pesquisadores e desenvolvedores, agregando a produção científica sobre SAD, e podendo servir como uma referência inicial para o desenvolvimento de outros SAD clínicos para dispositivos móveis.

ANEXOS

ANEXO A

Normas de formatação do periódico Health Informatics Journal

Manuscript Submission Guidelines: *Health Informatics Journal*

This Journal recommends that authors follow the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals formulated by the International Committee of Medical Journal Editors (ICMJE).

Please read the guidelines below then visit the Journal's submission site <http://mc.manuscriptcentral.com/hij> to upload your manuscript. Please note that manuscripts not conforming to these guidelines may be returned.

Only manuscripts of sufficient quality that meet the aims and scope of *Health Informatics Journal* will be reviewed.

As part of the submission process you will be required to warrant that you are submitting your original work, that you have the rights in the work, that you are submitting the work for first publication in the Journal and that it is not being considered for publication elsewhere and has not already been published elsewhere, and that you have obtained and can supply all necessary permissions for the reproduction of any copyright works not owned by you.

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1. What do we publish?

1.1 Aims & Scope

Before submitting your manuscript to Health Informatics Journal, please ensure you have read the [Aims & Scope](#).

1.2 Article Types

Representing the interdisciplinary nature of health informatics, *Health Informatics Journal* welcomes contributions of original research or original contributions to the existing literature on health informatics.

Your manuscript should ideally be between 3000 and 4000 words long. Please also supply an abstract of 100-150 words, and up to five keywords, arranged in alphabetical order.

1.3 Writing your paper

The SAGE Author Gateway has some general advice and on [how to get published](#), plus links to further resources.

1.3.1 Make your article discoverable

When writing up your paper, think about how you can make it discoverable. The title, keywords and abstract are key to ensuring readers find your article through search engines such as Google. For information and guidance on how best to title your article, write your abstract and select your keywords, have a look at this page on the Gateway: [How to Help Readers Find Your Article Online](#).

2. Editorial policies

2.1 Peer review policy

Health Informatics Journal is an international peer reviewed journal. All papers submitted to *Health Informatics Journal* are subject to peer review by members of a carefully appointed editorial board. The journal operates a double blind reviewing policy. Each paper submitted, if considered suitable by the Editor, will be refereed by at least two anonymous referees.

As part of the submission process you will be asked to provide the names of peers who could be called upon to review your manuscript. Recommended reviewers should be experts in their fields and should be able to provide an objective assessment of the manuscript. Please be aware of any conflicts of interest when recommending reviewers. Examples of conflicts of interest include (but are not limited to) the below:

- The reviewer should have no prior knowledge of your submission,
- The reviewer should not have recently collaborated with any of the authors,
- Reviewer nominees from the same institution as any of the authors are not permitted.

Please note that the Editors are not obliged to invite any recommended/opposed reviewers to assess your manuscript.

2.2 Authorship

Papers should only be submitted for consideration once consent is given by all contributing authors. Those submitting papers should carefully check that all those whose work contributed to the paper are acknowledged as contributing authors.

The list of authors should include all those who can legitimately claim authorship. This is all those who:

- (i) Made a substantial contribution to the concept or design of the work; or acquisition, analysis or interpretation of data,
- (ii) Drafted the article or revised it critically for important intellectual content,
- (iii) Approved the version to be published,
- (iv) Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content.

Authors should meet the conditions of all of the points above. When a large, multicentre group has conducted the work, the group should identify the individuals who accept direct responsibility for the manuscript. These individuals should fully meet the criteria for authorship.

Acquisition of funding, collection of data, or general supervision of the research group alone does not constitute authorship, although all contributors who do not meet the criteria for authorship should be listed in the Acknowledgments section. Please refer to the [International Committee of Medical Journal Editors \(ICMJE\)](#) authorship guidelines for more information on authorship.

2.3 Acknowledgements

All contributors who do not meet the criteria for authorship should be listed in an Acknowledgements section. Examples of those who might be acknowledged include a person who provided purely technical help, or a department chair who provided only general support.

Any acknowledgements should appear first at the end of your article prior to your Declaration of Conflicting Interests (if applicable), any notes and your References.

2.4 Funding

To comply with the guidance for Research Funders, Authors and Publishers issued by the Research Information Network (RIN), *Health Informatics Journal* additionally requires all Authors to acknowledge their funding in a consistent fashion under a separate heading. All research articles should have a funding acknowledgement in the form of a sentence as follows, with the funding agency written out in full, followed by the grant number in square brackets:

This work was supported by the Medical Research Council [grant number xxx].

Multiple grant numbers should be separated by comma and space. Where the research was supported by more than one agency, the different agencies should be separated by semi-colon, with “and” before the final funder. Thus:

This work was supported by the Wellcome Trust [grant numbers xxxx, yyyy]; the Natural Environment Research Council [grant number zzzz]; and the Economic and Social Research Council [grant number aaaa].

In some cases, research is not funded by a specific project grant, but rather from the block grant and other resources available to a university, college or other research institution. Where no specific funding has been provided for the research we ask that corresponding authors use the following sentence:

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Please include this information under a separate heading entitled “Funding” directly after any other Acknowledgements prior to your “Declaration of Conflicting Interests” (if applicable), any Notes and your References.

Important note: If you have any concerns that the provision of this information may compromise your anonymity dependent on the peer review policy of this journal outlined above, you can withhold this information until final accepted manuscript.

For more information on the guidance for Research Funders, Authors and Publishers, please visit the [Research Information Network](#) website.

2.5 Declaration of conflicting interests

Health Informatics Journal encourages authors to include a declaration of any conflicting interests and recommends you review the good practice guidelines on the [SAGE Journal Author Gateway](#).

3. Publishing Policies

3.1 Publication ethics

SAGE is committed to upholding the integrity of the academic record. We encourage authors to refer to the Committee on Publication Ethics' [International Standards for Authors](#) and view the Publication Ethics page on the [SAGE Author Gateway](#).

3.1.1 Plagiarism

Health Informatics Journal and SAGE take issues of copyright infringement, plagiarism or other breaches of best practice in publication very seriously. We seek to protect the rights of our authors and we always investigate claims of plagiarism or misuse of published articles. Equally, we seek to protect the reputation of the journal against malpractice. Submitted articles may be checked with duplication-checking software. Where an article, for example, is found to have plagiarised other work or included third-party copyright material without permission or with insufficient acknowledgement, or where the authorship of the article is contested, we reserve the right to take action including, but not limited to: publishing an erratum or corrigendum (correction); retracting the article; taking up the matter with the head of department or dean of the author's institution and/or relevant academic bodies or societies; or taking appropriate legal action.

3.1.2 Prior publication

If material has been previously published it is not generally acceptable for publication in a SAGE journal. However, there are certain circumstances where previously published material can be considered for publication. Please refer to the guidance on the [SAGE Author Gateway](#) or if in doubt, contact the Editor at the address given below.

3.2 Contributor's publishing agreement

Before publication, SAGE requires the author as the rights holder to sign a Journal Contributor's Publishing Agreement. SAGE's Journal Contributor's Publishing Agreement is an exclusive licence agreement which means that the author retains copyright in the work but grants SAGE the sole and exclusive right and licence to publish for the full legal term of copyright. Exceptions may exist where an assignment of copyright is required or preferred by a proprietor other than SAGE. In this case copyright in the work will be assigned from the author to the society. For more information please visit the [SAGE Author Gateway](#).

3.3 Open access and author archiving

Health Informatics Journal offers optional open access publishing via the SAGE Choice programme. For more information please visit the [SAGE Choice website](#). For information on funding body compliance, and depositing your article in repositories, please visit [SAGE Publishing Policies](#) on our Journal Author Gateway.

4. Preparing your manuscript for submission

4.1 Formatting

The preferred format for your manuscript is Word. LaTeX files are also accepted. Word and (La)Tex templates are available on the [Manuscript Submission Guidelines](#) page of our Author Gateway.

4.2 Artwork, figures and other graphics

For guidance on the preparation of illustrations, pictures and graphs in electronic format, please visit SAGE's [Manuscript Submission Guidelines](#).

Figures supplied in colour will appear in colour online regardless of whether or not these illustrations are reproduced in colour in the printed version. For specifically requested colour reproduction in print, you will receive information regarding the costs from SAGE after receipt of your accepted article.

4.3 Supplementary material

Health Informatics Journal does not currently accept supplemental files.

4.4 Reference style

Health Informatics Journal adheres to the SAGE Vancouver reference style. View the [SAGE Vancouver guidelines](#) to ensure your manuscript conforms to this reference style.

If you use [EndNote](#) to manage references, you can download the [SAGE Vancouver EndNote output file](#)

4.5 English language editing services

Authors seeking assistance with English language editing, translation, or figure and manuscript formatting to fit the journal's specifications should consider using [SAGE Language Services](#). Visit SAGE Language Services on our Journal Author Gateway for further information.

5. Submitting your manuscript

Health Informatics Journal is hosted on SAGE Track, a web based online submission and peer review system powered by ScholarOne™ Manuscripts. Visit <http://mc.manuscriptcentral.com/hij> to login and submit your article online.

IMPORTANT: Please check whether you already have an account in the system before trying to create a new one. If you have reviewed or authored for the journal in the past year it is likely that you will have had an account created. For further guidance on submitting your manuscript online please visit [ScholarOne Online Help](#).

5.1 ORCID

As part of our commitment to ensuring an ethical, transparent and fair peer review process SAGE is a supporting member of ORCID, the Open Researcher and Contributor ID. ORCID provides a persistent digital identifier that distinguishes researchers from every other

researcher and, through integration in key research workflows such as manuscript and grant submission, supports automated linkages between researchers and their professional activities ensuring that their work is recognised.

We encourage all authors to add their ORCID IDs to their SAGE Track accounts and include their ORCID IDs as part of the submission process. If you don't already have one you can create one [here](#).

5.2 Information required for completing your submission

You will be asked to provide contact details and academic affiliations for all co-authors via the submission system and identify who is to be the corresponding author. These details must match what appears on your manuscript. At this stage please ensure you have included all the required statements and declarations and uploaded any additional supplementary files (including reporting guidelines where relevant).

5.3 Permissions

Please also ensure that you have obtained any necessary permission from copyright holders for reproducing any illustrations, tables, figures or lengthy quotations previously published elsewhere. For further information including guidance on fair dealing for criticism and review, please see the Copyright and Permissions page on the [SAGE Author Gateway](#).

6. On acceptance and publication

6.1 SAGE Production

Your SAGE Production Editor will keep you informed as to your article's progress throughout the production process. Proofs will be sent by PDF to the corresponding author and should be returned promptly. Authors are reminded to check their proofs carefully to confirm that all author information, including names, affiliations, sequence and contact details are correct, and that Funding and Conflict of Interest statements, if any, are accurate. Please note that if there are any changes to the author list at this stage all authors will be required to complete and sign a form authorising the change.

6.2 Online First publication

Online First allows final articles (completed and approved articles awaiting assignment to a future issue) to be published online prior to their inclusion in a journal issue, which significantly reduces the lead time between submission and publication. Visit the [SAGE Journals help page](#) for more details, including how to cite Online First articles.

6.3 Access to your published article

SAGE provides authors with online access to their final article.

6.4 Promoting your article

Publication is not the end of the process! You can help disseminate your paper and ensure it is as widely read and cited as possible. The SAGE Author Gateway has numerous resources to help you promote your work. Visit the [Promote Your Article](#) page on the Gateway for tips and advice. In addition, SAGE is partnered with Kudos, a free service that allows authors to explain, enrich, share, and measure the impact of their article. Find out how to [maximise your article's impact with Kudos](#).

6.5 Informed consent

Submitted manuscripts should be arranged according to the "Uniform Requirements for Manuscripts Submitted to Biomedical Journals". The full document is available at <http://icmje.org>. When submitting a paper, the author should always make a full statement

to the Editor about all submissions and previous reports that might be regarded as redundant or duplicate publication of the same or very similar work.

Ethical considerations: All research on human subjects must have been approved by the appropriate research body in accordance with national requirements and must conform to the principles embodied in the Declaration of Helsinki (<http://www.wma.net>) as well as to the International Ethical Guidelines for Biomedical Research Involving Human Subjects and the International Guidelines for Ethical Review for Epidemiological Studies (<http://www.cioms.ch>). An appropriate statement about ethical considerations, if applicable, should be included in the methods section of the paper.

6.6 Ethics

When reporting experiments on human subjects, indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) or with the Declaration of Helsinki 1975, revised Hong Kong 1989. Do not use patients' names, initials or hospital numbers, especially in illustrative material. When reporting experiments on animals, indicate which guideline/law on the care and use of laboratory animals was followed.

7. Further information

Any correspondence, queries or additional requests for information on the manuscript submission process should be sent to the *Health Informatics Journal* editorial office as follows:

Rob Procter
Editor, Health Informatics Journal
Email: hijeditor@inf.ed.ac.uk

ANEXO B

Normas complementares para submissão em periódicos da SAGE

Manuscript Submission Guidelines

1. [Pre-submission: helping readers find your article](#)
2. [Submitting your article](#)
3. [Editorial policies](#)
 - 3.1 [Peer review policy](#)
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 - 4.2 [Contributor's publishing agreement](#)
 - 4.3 [Open access and author archiving](#)
 - 4.4 [Permissions](#)
5. [Preparing your manuscript](#)
 - 5.1 [Formatting your article](#)
 - 5.2 [\(La\)TeX template and guidelines](#)
 - 5.3 [Artwork guidelines](#)
 - 5.4 [English language editing services](#)
6. [Submitting your manuscript](#)
 - 6.1 [How to submit your manuscript](#)
 - 6.2 [Title, keywords and abstracts](#)
 - 6.3 [ORCID](#)
7. [On acceptance and publication](#)
 - 7.1 [SAGE Production](#)
 - 7.2 [Access to your published article](#)
 - 7.3 [Online First publication](#)

Pre-submission: helping readers find your article

Before you submit your manuscript, go back and review your title, keywords and abstract. These elements are key to ensuring that readers will be able to find your article online through online search engines such as Google. More information and guidance on how best to title your article, write your abstract and select your keywords can be found here: [How to Help Readers Find Your Article Online](#).

One simple thing you can do to improve your article's visibility and ensure proper indexing and cross-linking is to provide **full names for all authors**. Please refer to [our guidelines for author names](#), prepared in consultation with Google Scholar, for more information.

Submitting your article

Each SAGE journal has its own editorial office and its own instructions for authors. To submit your article, visit your chosen journal's homepage and click on the manuscript submission guidelines link. View the [list of all our journals here](#).

Our general guidance for authors can be found below. Please be sure to read your chosen journal's guidelines as each journal will have its own specific requirements. Please direct queries on the submission process to the journal's editorial office; details can be found within each journal's submission guidelines. Other queries may be sent to authorqueries@sagepub.co.uk

SAGE is a member of the [Committee on Publication Ethics](#) (COPE) and follows their best practice guidelines.

For authors submitting to medical journals, SAGE recommends that authors follow the [Uniform Requirements for Manuscripts Submitted to Biomedical Journals](#) formulated by the [International Committee of Medical Journal Editors](#) (ICMJE).

Are you choosing the right journal for your research? With so many journals to choose from you may need a little guidance...

[Think, check, submit](#) is a trusted online service with a useful checklist that will help you determine whether you are submitting to the right journal. If you can answer 'yes' to most of their questions then you can be confident that your chosen journal is easily discoverable with a suitable reputation.

Editorial policies

Peer review policy

Please see the submission guidelines of the journal you wish to submit to. View the complete list of [SAGE Journals](#).

Please note that as part of the submission process you may be asked to provide the names of a number of peers who could be called upon to review your manuscript. Recommended reviewers should be experts in their fields and should be able to provide an objective assessment of the manuscript. Please be aware of any conflicts of interest when recommending reviewers. Examples of conflicts of interest include (but are not limited to) the below:

- The reviewer should have no prior knowledge of your submission
- The reviewer should not have recently collaborated with any of the authors
- Reviewer nominees from the same institution as any of the authors are not permitted

Please note that the journal's editors are not obliged to invite any recommended/opposed reviewers to assess your manuscript.

Authorship

For authors submitting to technical or medical journals, papers should only be submitted for consideration once consent is given by all contributing authors. Those submitting papers should carefully check that all those whose work contributed to the paper are acknowledged as contributing authors.

The list of authors should include all those who can legitimately claim authorship. This is all those who:

1. Made a substantial contribution to the concept and design, acquisition of data or analysis and interpretation of data,
2. Drafted the article or revised it critically for important intellectual content,
3. Approved the version to be published.

Authors should meet the conditions of all of the points above. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content.

When a large, multicentre group has conducted the work, the group should identify the individuals who accept direct responsibility for the manuscript. These individuals should fully meet the criteria for authorship.

Acquisition of funding, collection of data, or general supervision of the research group alone does not constitute authorship, although all contributors who do not meet the criteria for authorship should be listed in the Acknowledgments section. Please refer to

the [International Committee of Medical Journal Editors \(ICMJE\) authorship guidelines](#) for more information on authorship.

For authors submitting to social science or humanities journals, all parties who have made a substantive contribution to the article should be listed as authors. Principal authorship, authorship order, and other publication credits should be based on the relative scientific or professional contributions of the individuals involved, regardless of their status. A student is usually listed as principal author on any multiple-authored publication that substantially derives from the student's dissertation or thesis.

Corresponding author

The one individual who takes primary responsibility for communication with the journal during the manuscript submission, peer review, and publication process, and typically ensures that all the journal's administrative requirements, such as providing details of authorship, ethics committee approval, clinical trial registration documentation, and gathering conflict of interest forms and statements, are properly completed, although these duties may be delegated to one or more co-authors.

The corresponding author is the person who signs the publishing agreement on behalf of all of the authors and whose contact details are included on the article. They should be available after publication to respond to critiques of the work and cooperate with any requests from the journal for data or additional information should questions about the paper arise after publication.

General guidance for authors submitting to medical journals (please view the relevant journal's submission guidelines for specific requirements)

Research ethics and patient consent

Medical research involving human subjects must be conducted according to the [World Medical Association Declaration of Helsinki](#)

Submitted manuscripts should conform to the [ICMJE Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals](#), and all papers reporting animal and/or human studies must state in the methods section that the relevant Ethics Committee or Institutional Review Board provided (or waived) approval. Please ensure that you have provided the full name and institution of the review committee, in addition to the approval number.

For research articles, authors are also required to state in the methods section whether participants provided informed consent and whether the consent was written or verbal.

Information on informed consent to report individual cases or case series should be included in the manuscript text. A statement is required regarding whether written informed consent for patient information and images to be published was provided by the patient(s) or a legally authorized representative.

Please also refer to the [ICMJE Recommendations for the Protection of Research Participants](#)

All research involving animals submitted for publication must be approved by an ethics committee with oversight of the facility in which the studies were conducted.

Clinical trials

Many SAGE journals conform to the [ICMJE requirement](#) that clinical trials are registered in a WHO-approved public trials registry at or before the time of first patient enrolment as a condition of consideration for publication. The trial registry name and URL, and registration number must be included at the end of the abstract.

Further to the above, other SAGE journals may consider retrospectively registered trials if the justification for late registration is acceptable, consistent with the [AllTrials campaign](#). The

trial registry name and URL, and registration number must be included at the end of the abstract.

Reporting guidelines

The relevant [EQUATOR Network](#) reporting guidelines should be followed depending on the type of study. For example, all randomized controlled trials submitted for publication should include a completed [Consolidated Standards of Reporting Trials \(CONSORT\)](#) flow chart as a cited figure, and a completed CONSORT checklist as a supplementary file.

Other resources can be found at [NLM's Research Reporting Guidelines and Initiatives](#)

Publishing Policies

Publication ethics

SAGE is committed to upholding the integrity of the academic record. We encourage authors to refer to the Committee on Publication Ethics' [International Standards for Authors](#) and view the Publication Ethics page on the [SAGE Author Gateway](#)

Plagiarism

SAGE takes issues of copyright infringement, plagiarism or other breaches of best practice in publication very seriously. We seek to protect the rights of our authors and we always investigate claims of plagiarism or misuse of published articles. Equally, we seek to protect the reputation of the journal against malpractice. Submitted articles may be checked with duplication-checking software. Where an article, for example, is found to have plagiarised other work or included third-party copyright material without permission or with insufficient acknowledgement, or where the authorship of the article is contested, we reserve the right to take action including, but not limited to: publishing an erratum or corrigendum (correction); retracting the article; taking up the matter with the head of department or dean of the author's institution and/or relevant academic bodies or societies; or taking appropriate legal action.

Previous distribution and/or publication

The author should disclose any prior distribution and/or publication of any portion of the material to the Editor for the Editor's consideration and ensure that appropriate attribution to the prior distribution and/or publication of the material is included. For more information, visit our [Prior Publication](#) page on the SAGE Journal Author Gateway.

Contributor's publishing agreement

Before publication, SAGE requires the author as the rights holder to sign a Journal Contributor's Publishing Agreement. SAGE's Journal Contributor's Publishing Agreement for traditional subscription journals is an exclusive licence agreement which means that the author retains copyright in the work but grants SAGE the sole and exclusive right and licence to publish for the full legal term of copyright. Exceptions may exist where an assignment of copyright is required or preferred by a proprietor other than SAGE. In this case copyright in the work will be assigned from the author to the society. This licence enables authors to make articles open access by archiving their article at no charge via the [green open access archiving](#) route. Authors who have published in a subscription journal can do this by depositing the version of the article accepted for publication (version 2) in their own institution's repository.

For more information please visit our [Frequently Asked Questions](#) on the SAGE Journal Author Gateway.

SAGE Choice - publishing open access in a subscription journal

The [SAGE Choice](#) program offers authors the option to make their articles freely available

upon publication in most subscription-based SAGE journals. It also enables authors to comply with funding body requirements, where publishing research papers open access is a stipulation of funding, while still publishing their article in the subscription journal of their choice. The licence used is the same open access contributor's publishing agreement.

Open Access contributor's publishing agreement

SAGE open access journals all publish articles under [Creative Commons](#) licences. The standard licence is Creative Commons by Attribution Non-Commercial (CC BY-NC), which allows others to re-use the work without permission as long as the work is properly referenced and the use is non-commercial. Alternative licence arrangements are available, for example, to meet particular funder mandates, made at the author's request. For more information, you are advised to visit SAGE's [open access licences page](#).

Permissions

Authors are responsible for obtaining permission from copyright holders for reproducing any illustrations, tables, figures or lengthy quotations previously published elsewhere. For further information including guidance on fair dealing for criticism and review, please visit our [Frequently Asked Questions](#) on the [SAGE Journal Author Gateway](#)

Preparing your manuscript

Formatting your article

When formatting your references, please ensure you check the reference style followed by your chosen journal. Here are quick links to the [SAGE Harvard](#) reference style, the [SAGE Vancouver](#) reference style and the [APA](#) reference style.

Other styles available for certain journals are: [ACS Style Guide](#), [AMA Manual of Style](#), [ASA Style Guide](#), [Chicago Manual of Style](#) and [CSE Manual for Authors, Editors, and Societies](#).

Please refer to [your journals' manuscript submission guidelines](#) to confirm which reference style it conforms to and for other specific requirements.

Equations should to be submitted using Office Math ML and Math type.

Word template and guidelines

Our tailored [Word template](#) and [guidelines](#) will help you format and structure your article, with useful general advice and Word tips.

(La)TeX guidelines

We welcome submissions of LaTeX files. Please download the [SAGE LaTeX Template](#), which contains comprehensive guidelines.

If you have used any .bib files when creating your article, please include these with your submission so that we can generate the reference list and citations in the journal-specific style. Review our [LaTeX Frequently Asked Questions](#). If you still need additional help, please email SageTeXsupport@sagepub.com

Artwork guidelines

Illustrations, pictures and graphs, should be supplied with the highest quality and in an electronic format that helps us to publish your article in the best way possible. Please follow the guidelines below to enable us to prepare your artwork for the printed issue as well as the online version.

- **Format:** TIFF, JPEG: Common format for pictures (containing no text or graphs). EPS: Preferred format for graphs and line art (retains quality when enlarging/zooming in).
- **Placement:** Figures/charts and tables created in MS Word should be included in the main text rather than at the end of the document.

Figures and other files created outside Word (i.e. Excel, PowerPoint, JPG, TIFF, EPS, and PDF) should be submitted separately. Please add a placeholder note in the running text (i.e. "[insert Figure 1

- .J")
- **Resolution:** Rasterized based files (i.e. with .tiff or .jpeg extension) require a resolution of at least **300 dpi** (dots per inch). Line art should be supplied with a minimum resolution of **800 dpi**.
- **Colour:** Please note that images supplied in colour will be published in colour online and black and white in print (unless otherwise arranged). Therefore, it is important that you supply images that are comprehensible in black and white as well (i.e. by using colour with a distinctive pattern or dotted lines). The captions should reflect this by **not** using words indicating colour.
- **Dimension:** Check that the artworks supplied match or exceed the dimensions of the journal. Images **cannot** be scaled up after origination
- **Fonts:** The lettering used in the artwork should not vary too much in size and type (usually sans serif font as a default).

English language editing services

Authors seeking assistance with English language editing, translation, or figure and manuscript formatting to fit the journal's specifications should consider using SAGE Language Services. Visit [SAGE Language Services](#) on our Journal Author Gateway for further information.

Submitting your manuscript

How to submit your manuscript

Many SAGE journals are hosted on SAGE Track, a web based online submission and peer review system powered by ScholarOne™ Manuscripts. Please see the submission guidelines of the journal you wish to submit to find out its preferred submission method.

IMPORTANT: If submitting through SAGE Track, please check whether you already have an account in the system before trying to create a new one. If you have reviewed or authored for the journal in the past year it is likely that you will have had an account created. For further guidance on submitting your manuscript online please visit ScholarOne Online Help.

Title, keywords and abstracts

You will be asked to supply a title, short title, an abstract and keywords to accompany your article. The title, keywords and abstract are key to ensuring readers find your article online through online search engines such as Google. Please refer to the information and guidance on how best to title your article, write your abstract and select your keywords by visiting the SAGE Journal Author Gateway for guidelines on [How to Help Readers Find Your Article Online](#)

Video abstracts

Some journals accept video abstracts (please check the submission guidelines of your chosen journal). Read our guidelines on [how to produce a video abstract](#)

ORCID

ORCID (<http://orcid.org>) provides an identifier for individuals to use with their name as they engage in research, scholarship, and innovation activities. SAGE supports the use of

ORCID and provides authors with the facility to include their ORCID identifier on submission, in order to enable transparent and trustworthy connections between researchers, their contributions, and affiliations. Please visit the [ORCID page](#) for more information.

On acceptance and publication

SAGE Production

Your SAGE Production Editor will keep you informed as to your article's progress throughout the production process. Proofs will be sent by PDF to the corresponding author and should be returned promptly.

Access to your published article

SAGE provides authors with online access to their final article.

Online First publication

Many SAGE journals offer Online First. Online First allows final revision articles (completed articles in queue for assignment to an upcoming issue) to be published online prior to their inclusion in a final journal issue which significantly reduces the lead time between submission and publication. For more information please visit our [Online First Fact Sheet](#)

ANEXO C

Normas para formatação de referências pelo estilo SAGE Vancouver

6.2 SAGE Vancouver

1. General

1. Reference numbers have full points in the reference list.
2. Please ensure that publications are referenced in the order in which they appear in the text.
3. Journal titles should be abbreviated according to the standard in the Index Medicus. If unsure, please check for any inconsistencies within reference lists. For STM journals, please refer also to the following: <http://scieng.library.ubc.ca/coden/>.
4. Do not separate initials with spaces or full points, but add a full point after last initial before the title.
5. Up to three authors may be listed. If more, then list the first three authors and represent the rest by et al. Fewer author names followed by et al. is also acceptable. Where et al. is used, it should always be upright, not italic in both references and textual citations.
6. Last Names containing de, van, von, De, Van, Von, de la, etc. should be listed under D and V respectively. List them as: De Roux DP and not Roux DP, de. When cited in the main text without the first name, use capitals for De, Van, Von, De la, etc. (Van Dijk, year)
7. Names containing Jr or II should be listed as follows: • Author Last Name Initial Jr (year)
• Author Last Name Initial II (year)

2. Text citations

Please use superscript numerals *after* the punctuation (STM) or numbers in square brackets (HSS), and check that it corresponds to the correct number in the reference list.

3. Reference styles

Book

1. Huff D. *How to lie with statistics*. 4th ed. London: Penguin, 1991, p.51.

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1. Huff D and Black TL. Comprehensive statistics. In: Miller C and Smith H (eds) *How to lie with statistics*. 4th ed. London: Penguin, 1991, pp.51–55.

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2. Araki C, Black TL, Patberg FT, et al. Significance of calf muscle pump function in venous ulceration. *J Vasc Surg* 1994; 20: 872–879.

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Conference paper

1. Peters J. Musculo-venous pumps in the human lower limb. In: *ASME conference on automatic transmissions* (ed A O'Brien), Pisa, Italy, 29 May–2 June 2003, paper no. GE1234, pp.4–10. New York: ASME.

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1. Clark JM. *Referencing style for journals*. PhD Thesis, University of Leicester, UK, 2002.

Patent and patent applications

1. Smith ST. *Referencing styles for journals – a new method*. Patent 12346-ZH, USA, 2011.
2. Jones P. *Referencing styles for journals – a new method*. Patent application 12346-ZHA, USA, 2011.

Report (published/unpublished)

1. MacDonald S. *The state of social welfare in the UK*. Report, University of Durham, UK, June 2011.
2. Citigroup Ltd. *How to make your money work for you*. Report for the Department of Finance. Report no. 123345, 13 June 2011. Oxford: OUP.

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1. Clark JM. *A new exhaust gasket manifold for powertrains*. SAE paper 2002-0101234, 2002.

Newspaper/magazine

1. Clark JM. *Referencing style for journals*. *The Independent*, 21 May 2006, p.10.

Package insert (medical etc.)

1. Eisai Inc. *Aloxi (package insert)*. New York: Esai Inc, 2008.

Manual (automotive etc.)

1. Fiat. *Driver's manual*, Fiat Uno 4-litre diesel model, December 2010.

Standard

1. ISO 27799:2008. *Information security management in health*.

ANEXO D**Certificado de Registro do projeto na Comissão de Pesquisa da Universidade
Federal de Ciências da Saúde de Porto Alegre**REPÚBLICA FEDERATIVA DO BRASIL
MINISTÉRIO DA EDUCAÇÃO**UFCSPA**UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE PORTO ALEGRE
COMISSÃO DE PESQUISA**Certificado**

Certificamos que o projeto de pesquisa intitulado "*Sistema de apoio à decisão em reabilitação cardiopulmonar e metabólica Fase II*", de Rodrigo Della Mèa Plentz, está registrado na Comissão de Pesquisa da Universidade Federal de Ciências da Saúde de Porto Alegre sob o número 042/2016. Salientamos que este registro **não autoriza o pesquisador a coletar ou analisar dados oriundos de sujeitos de pesquisa.**

Salientamos ainda que tal registro **não garante** a concessão de recursos financeiros por parte da UFCSPA a este projeto de pesquisa.

Porto Alegre, 30 de novembro de 2016.

Pedro Ricardo Gazzola Zen
Coordenador Geral da Pesquisa
UFCSPA