Decision Support for Teletraining of COPD Patients

B. Song[1]; K.-H. Wolf[1]; M. Gietzelt[1]; O. Al Scharaa[1]; U. Tegtbur[2]; R. Haux[1]; M. Marschollek[3]

[1]Peter L. Reichertz Institute for Medical Informatics, University of Braunschweig – Institute of Technology and Hannover Medical School, Braunschweig, Germany;
[2]Institute for Sports Medicine, Hannover Medical School, Hannover, Germany;
[3]Peter L. Reichertz Institute for Medical Informatics, University of Braunschweig – Institute of Technology and Hannover Medical School, Hannover, Germany

Keywords

COPD, decision support, JBoss Drools, Arden Syntax, training control

Summary

Background: Supervised physical training has been shown to promote rehabilitation of patients affected by chronic obstructive pulmonary disease (COPD). Currently, due to limited resources, not all COPD patients can be trained by an expert supervisor.
Objectives: The objective of our research is to construct a decision support system (DSS) which observes and controls physical ergometer training sessions of COPD patients.
Methods: A systematic literature review and expert interviews were carried out to build up the knowledge base for the DSS.
Results: Nine production rules were established and standardized by Drools and Arden Syntax. The developed software autonomously controls training sessions on a bicycle ergometer on the basis of vital signs data. Thus it offers a new way for the rehabilitation of COPD patients.
Conclusion: Evaluation with nine healthy subjects in a laboratory environment has confirmed its correct function, but the effects of its use for COPD patients' rehabilitation and their quality of life have to be investigated in a further study.

Correspondence to:
Bianying Song
Peter L. Reichertz Institute for Medical Informatics
University of Braunschweig – Institute of Technology
and Hannover Medical School
Mühlenpfordtstraße 23
38106 Braunschweig
Germany
E-mail: bianying.song@plri.de

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1. Introduction

Chronic obstructive pulmonary disease (COPD) is a research focus in medicine. In recent years, new relevant works for essential aspects of the disease (diagnosis, medication and non-medication therapy, management of exacerbations, operational procedures) have been published [1]. There are mainly two reasons for this. First: the large number of patients and the high mortality. The global prevalence of COPD is estimated to be 8.5% among the population aged over 40 years [2]. COPD is the sixth leading cause of death and the fifth leading cause of disability worldwide [3]. Second: the enormous socioeconomic importance of COPD. In several studies, the annual costs of COPD have been calculated: in the United States the annual cost of COPD in 2002 is estimated to be $32.1 billion [4], in Germany to be €5.93 billion in 2000 [5], and in Japan to be ¥805.5 billion (US$6.8 billion) [6].

COPD can't be fully cured according to current medical standards. Medication therapy can only reduce the symptoms. Therefore, a concurrent training therapy appears to be crucial [7]. Long-term physical training improves strength and endurance, relieves dyspnea, reduces the fear of dyspnea and increases the quality of life [8].

Ergometer training is one of the traditional training methods for COPD patients [9]. Professional supervision during ergometer training of COPD patients is preferable, because it makes training more effective [10]. Training intensity and mode are directly related to patients' safety and training effectiveness, and thus are very important control factors. But due to limited financial and human resources, not all COPD patients can be trained by an expert supervisor, especially because frequent sessions (three to five times per week) are indicated [11]. With the development of information and communication technology, health-enabling technologies and decision support systems (DSS) are widely researched in health care [12–15]. A knowledge-based DSS may autonomously supervise and control physical training of COPD patients.

Teletraining is defined as "enabling the person to train at his preferred time and at his preferred place, thereby supervised adequately on distance by a care provider" [16]. The effect of teletraining of COPD patients should preferably have the same quality as the traditional training method (face to face feedback). In order to achieve this goal, telemonitoring and a DSS may be utilized. Telemonitoring is defined in [16] as "guarding the health condition of a subject by measuring and interpreting vital biosignals without interfering of the subject's activities of daily living but assure assistance and react when required". Telemonitoring and teletraining, which are indispensable parts of pervasive health [17, 18], can enable COPD patients to exercise at home under supervision. Hein et al. have demonstrated the technical feasibility of telemonitoring and teletraining for cardiovascular patients [19].

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2. Objectives

The aims of our research are to

1. establish and standardize a knowledge base for physical training of COPD patients,
2. develop and evaluate a software including a DSS which can remotely supervise and control the training of COPD patients autonomously.

3. Methods

3.1 Knowledge Acquisition

Production rules are used as a means for knowledge representation in our DSS. A systematic literature search and expert interviews were carried out to acquire relevant rules.

3.1.1 Literature Review

Three literature databases have been used in this phase to extract rules. These are: PUBMED/MEDLINE, BISP (Federal Institute for Sports Science, Germany) [20] and IEEE Xplore. The search was performed from March 30 to April 6, 2008. The keywords used and returned numbers of hits are listed in ▶Table 1. It shows that there are many articles about training of COPD patients, but very few contain explicit training rules. Papers written in English, German and Chinese were considered. The abstracts were selected with regard to reference to exercise intensities, exercise types, supervision parameters, training safety or existence of a control group. Review articles on physical training of COPD patients were carefully analyzed. Despite the magnitude of scientific literature, we found only two rules in [11] during this phase. These two rules were recommended to use in the context of ambulatory training.

3.1.2 Expert Interviews

An expert with many years of experience in training COPD patients (co-author UT, director of Institute for Sports Medicine at the Medical School Hannover), was interviewed twice to identify training planning and control rules. The interviews took place at two sessions on April 29 and May 5, 2008. The following are core statements:

- Training should be planned by using parameters gained in a level test and an endurance test (see section C).
- COPD patients should perform a 20- to 30-minute training every two days.
- Constant load is the most important factor during a training session.
- Training intensity can be assessed by measuring heart rate (HR).
- During the training, the oxygen saturation (SO_2) of COPD patients should not be less than 90%. HR, blood pressure (BP) and lactate levels should not rise continuously.

The two rules found in the previous literature review phase were supported by the expert. In the expert interviews phase, we found seven additional rules.

3.2 Knowledge Standardization

We use the Drools rule language to standardize the acquired rules [21]. A standardized rule contains a rule name, rule attributes, a left hand side and a right hand side. The rule name and rule attributes are optional. The left hand side is the conditional part of the rule, which follows a fixed syntax. The right hand side is basically a block that allows dialect-specific semantic code to be executed. In Drools, a standardized rule has a simple structure, e.g.:

```
rule "check SO2"
  salience 2
  when
    m : Message( SO2 < 90 )
  then
    m.reduceTrainingPerformance();
end
```

Drools use the Rete algorithm for rule matching [22]. This algorithm reorganizes all of the rules in a Rete net during the parsing phase. It can efficiently match the rules that have complex relationships. In addition, this algorithm can visualize rules through Rete nodes and their associations. This facilitates rule sharing and verification.

To facilitate knowledge sharing among health care providers, we also use the Arden Syntax for Medical Logic Modules [23], which is a part of the Health Level Seven (HL7) [24] standards since 1998, to standardize the rules. With Arden Syntax, a rule should be encoded into a Medical Logic Module (MLM). Thus, the above rule can be standardized in an MLM like this:

```
maintenance:
  title: MLM for test purposes;;
  mlmname: check SO2;;
```

Table 1 Returns from the databases

ID	Keywords	Hits		
		PUBMED	BISP	IEEE
1	COPD	32,703	44	42
2	Training COPD	1351	0	0
3	Exercise COPD	2738	0	0
4	Training COPD rules	1	0	0
5	Exercise COPD rules	1	0	0
6	Training COPD recommendations	44	0	0
7	Exercise COPD recommendations	31	0	0
8	Training COPD guideline	84	0	0
9	Exercise COPD guideline	50	0	0
10	Expert system training COPD	2	0	0
11	Decision aid training COPD	14	0	0
12	Decision support training COPD	14	0	0

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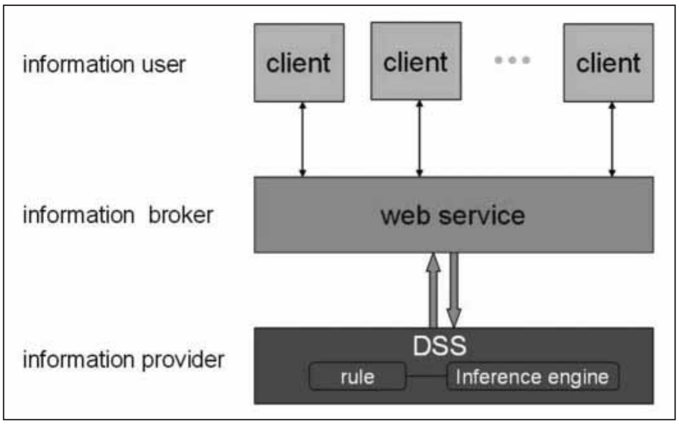

Fig. 1 Three-tier client server architecture in the system

```
  arden: Version 2.5;;
  version: 1.00;;
  institution: PLRI;;
  author: BS;;
  specialist: UT;;
  date: 2008-08-20;;
  validation: testing;;
library:
  purpose: test;;
  explanation: simple test MLM;;
  keywords:;;
  citations:;;
  links:;;
knowledge:
  type: data_driven;;
  data: (times, so2, performance, type) :=
    argument;
  ;;
  priority:;;
  evoke:;;
  logic:
  if so2 < 90 then
    performance := performance*0.85;
    conclude true;
  endif;
  ;;
  action:
  return performance;
  ;;
  urgency:;;
end:
```

Table 2 Knowledge base in the DSS

ID	Rules
1	If: SO_2 < 90% Then: reduce performance by 15%
2	If: SO2 < 80% Then: stop training
3	If: HR > maximum HR Then: stop training
4	If: HR increase > 5 beats per minute in the last 5 minutes Then: reduce performance by 15% (This rule should be checked starting at the 8th minute)
5	If: HR > coefficient × maximum HR Then: reduce performance by 15% (coefficient = 72% for A-Intensity, coefficient = 80% for B-Intensity, coefficient = 86% for C-Intensity)
6	If: systolic BP > 220 mmHg or diastolic BP > 180 mmHg Then: stop training
7	If: systolic BP increased > 5 mmHg in the last 3 measurements Then: reduce performance by 15% (This rule should be checked starting at the 5th measurement)
8	If: systolic BP > 180 mmHg Then: reduce performance by 15%
9	If: HR < 65% of the maximum HR Then: increase performance by 10% (This rule should be checked starting at the 9th minute)

The advantages and disadvantages of the two standardization methods are discussed later.

3.3 Defining the Training Schedule

Due to the individual physical fitness of COPD patients, level test and endurance test are used for defining a personal training plan. Training duration is set to 20 minutes. The training intensity performance is increased from 50% to 100% of the target performance intensity in the initial phase (the first two minutes) and reduced accordingly in the final phase (the last minute). In the remaining 17 minutes, the COPD patients perform their training with the target performance.

3.3.1 Level Test

A COPD patient begins the level test on an ergometer with a low initial performance (e.g. 5 watts). The performance is increased by 5 or 10 watts every minute until the patient is properly exhausted and can no longer exercise. The data of performance, HR and time are recorded during the test. The HR which corresponds to the maximum performance is the personal maximum HR. The following different training intensities are defined based on the personal maximum HR according to [25].

- A-intensity: 65–72% of maximum HR
- B-intensity: 72–80% of maximum HR
- C-intensity: 80–86% of maximum HR
- D-intensity: 86–97% of maximum HR

Please note that these recommendations are originally intended for patients who are affected by coronary artery disease (CAD). They still have to be validated for COPD patients.

Training intensity is assessed by measuring HR. Using the set of performance-HR-

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time data, training intensity can also be assessed by performance.

3.3.2 Endurance Test

Target performance is identified by using endurance test. At first, C-intensity is employed for a COPD patient. During an endurance test, the patient performs 20 minutes training with a performance which corresponds to 80% of the maximum HR. If the patients' HR is below 86% of the maximum HR, training performance is suitable as the target performance. If not, a lower intensity is recommended.

3.4 System Implementation

We used a three-tier client server architecture for the software implementation (▶Fig. 1). A plug-in for the open source software "Media Portal" was used as GUI [26]. The open source software JBoss Drools was used as the foundation of our DSS [21]. JBoss Drools is a business rule management system. It contains its own complete language, editor and compiler. The GUI and the DSS are connected by a web service.

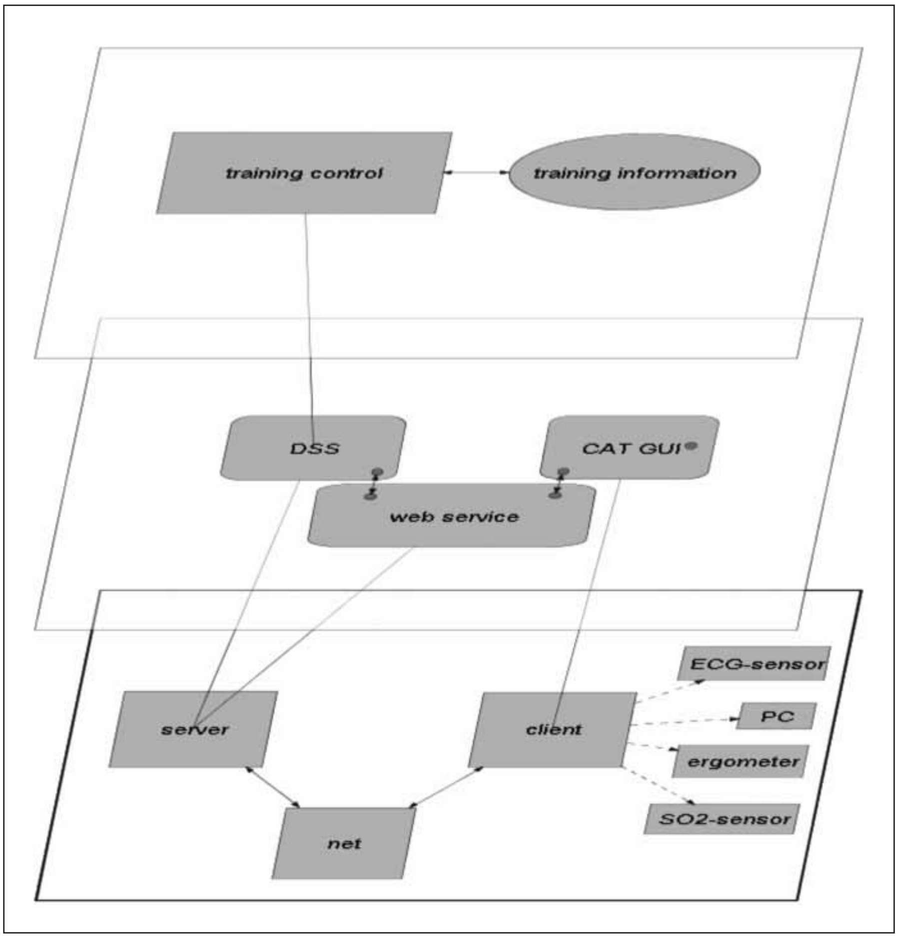

Fig. 2 The Three-layer Graph-based Meta Model of CAT. On top is the domain layer, in the middle is the application tool layer, the bottom is the physical tool layer.

4. Results

4.1 Knowledge Base

HR, BP and SO_2 have been chosen as parameters for the supervision of COPD patients. HR and SO_2 are measured every minute, BP every three minutes. Through the literature review and the expert interviews, a list of rules for controlling the training of COPD patients has been identified. The rules used in our DSS are listed in ▶Table 2.

4.2 The Software CAT

We developed a software called "COPD patients' assistant for physical training" (CAT) including a DSS. CAT autonomously controls the training on a bicycle ergometer according to the patient's physical status. CAT has a server program that contains the DSS and a client program. The server program is responsible for the regulation of the training intensity, fault-tolerance and writing protocol. If the server program receives an error value from the sensors, this error value is dropped and the previous correct value is used as the current value. All correctly measured values and all of the fired rules are recorded into a CSV file for tracking the training. The client program interacts with the SO_2 sensor (Nonin Avant 4100), ECG sensor (Corscience BT 12), ergometer (Daum Electronic ergo_bike premium8) and the GUI. Web services enable teletraining of COPD patients.

CAT's architecture is demonstrated using the Three-layer Graph-based Meta Model (▶Fig. 2) [27]. This meta model has been chosen because it is widely used in the domain of health information system architecture design, and because our system should be regarded as a part of a trans-institutional health information system in order to provide bidirectional interoperability with established hospital application systems.

The task "training control" and the object "training information" are shown at the domain layer. The task interprets and edits the object. The application components "DSS", "CAT GUI" and "web service" are shown at the logical tool layer. The "DSS" communicates with "CAT GUI" by the "web service". The association between the domain layer and the logical tool layer shows that the task "training control" is supported by the application component "DSS". The physical components "server", "net", "client", "sensor" and "ergometer" are shown at the physical tool layer. The associ-

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Fig. 3 Evaluation: The volunteer and the ergometer are on the left side, the GUI is shown on a digital TV set, sensors are on the body of the volunteer.

ations between the logical tool layer and the physical tool layer show which components are realized by which tools.

4.3 Evaluation with Healthy Volunteers

To test the functionality of the software including the DSS, an evaluation with nine healthy volunteers was carried out. In this evaluation, HR and SO_2 were measured by sensors. BP was set with fixed values (120/80 mmHg), because our sphygmomanometer cannot measure BP continuously. ►Figure 3 shows an exemplary training session of a volunteer (maximum HR: 197 beats per minute, suitable training intensity: C, target performance: 356 watts).

A training protocol graph can be found in ►Figure 4. In this protocol, the training performance of a volunteer was 178 watts in the initial phase (the first two minutes). The performance was 356 watts from the 3rd minute to the 8th minute. The performance was reduced by 15% in the 8th, 9th, 12th and 18th minute, respectively, because rule 4 was fired at these four moments (HR increase was larger than five beats per minute in the last five minutes). The performance was increased by 10% in the 14th and 15th minute, respectively, because rule 9 was fired at these two moments (HR was lower than the threshold (128 beats per minute)). The last minute was the final phase for cool down. Two types of rules were fired in this training session; altogether these two rules were fired six times.

5. Discussion

5.1 Rule-based Training Control

The COPD patients perform physical training using the prepared training plan. During the training, sensors measure vital parameters. Based on measured data, a standardized rule base is used to control training performance. This mechanism may make the home training of COPD patients safer and more efficient. Thus it offers a new way for the rehabilitation of COPD patients.

Level test and endurance test are used to create the personal training plan. Compared with other, more general methods such as the formula proposed in [28], our test-based method is more complex but more accurate, because the individual physical fitness is fully taken into account. The two tests should be made on two different days, so that they do not interfere with each other.

To supervise the physical status of COPD patients, HR, SO_2 and BP are used as parameters. Other parameters such as breath rate are reported for pre-training and post-training measurement in literature [10]. Breath rate could also be used as a supervision parameter during training. More research should be done in this area. In addition, lactate can also be used as a supervision parameter. At present, there is no lactate meter available, which is non-invasive and measures continually.

We use nine rules to control the training of COPD patients. Three rules abort the training when the patients are in danger. Five rules reduce the training performance by 15% if the patient is overloading. One rule increases training performance by 10% if the patient is light loading. The thresholds used in these rules are, for security reasons, "conservative" values. With these nine rules training of COPD patients can be controlled by a DSS at home, but this knowledge base still needs to be validated by different independent experts, because seven of our nine rules come from one expert. In addition, our knowledge base needs further refinement. On the one hand, it may be expanded by using other supervision parameters, e.g. breath rate; on the other hand, the expansion can be achieved through the refinement of existing rules.

The rules are standardized using the Drools rule language and the Arden Syntax for Medical Logic Modules. Using Drools to standardize the rules has three advantages: firstly, the standardized rule has a simple structure and does not have redundant information. Secondly, Drools has a complete development environment including a rule editor and a rule compiler. Thirdly, the Drools compiler uses the Rete algorithm to speed up rule matching. But Drools is a business rule management system. The rules which are encoded by Drools may not be accepted by a health provider. MLMs, in turn, have two advantages: firstly, the Arden Syntax is a part of the HL7 standard family and is well known by many healthcare providers. Secondly, it enables easy encoding of several essential medical concepts, e.g. temporal references. However, so far there is no standardized Arden compiler and Arden editor available. In addition, due to an issue known as the "curly braces" problem for MLMs [29], it is hard to deploy and transfer a DSS including MLMs.

5.2 The Architecture of CAT

A three-tier client server architecture is used in the software CAT for supporting

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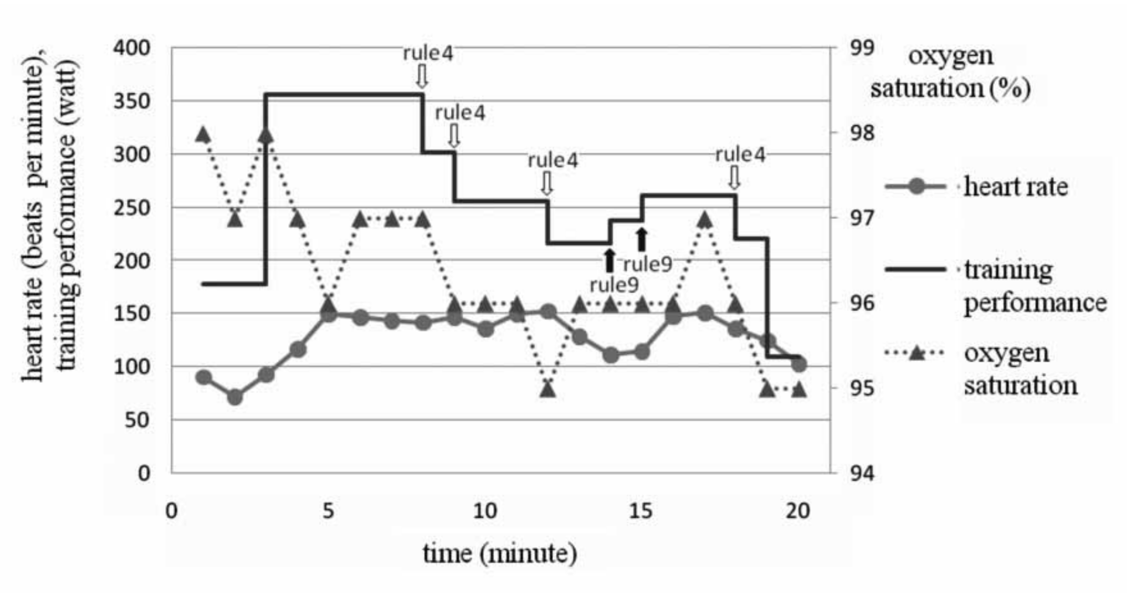

Fig. 4
A visualized training protocol

teletraining. The broker layer web service communicates with the client layer and the server layer. Web services are very suitable for home care software, because they use HTTP and thus can pass through a variety of firewalls. But poor security is its disadvantage. Web services use non-encrypted XML as communication messages. These messages cannot protect the patient's privacy. WS-security is a method to improve the safety of CAT.

5.3 Limitations and Future Work

There are some limitations that have to be mentioned with regard to our results:

5.3.1 Knowledge Base

Simple production rules are used in our knowledge base. The thresholds used in the rules can roughly control the physical training of COPD patients. But these rules are not yet adaptive for individual COPD patients. Fuzzy rules with an adaptive threshold might work better for the individual controlling.

For COPD patients who have extreme values for vital sign parameters already when resting, e.g. a low blood oxygen saturation (SO_2 <90%) or a high BP (systolic BP >180 mmHg), our fixed rules may not be appropriate to control a training session as they would continuously reduce performance. For safety reasons, these patients should be monitored by a physician.

5.3.2 Evaluation

The correct functions of the software CAT including the DSS have been confirmed in laboratory environment tests with young and healthy volunteers. But the effects of its use for COPD patients' rehabilitation and their quality of life as well as the correctness of the rule base have to be evaluated in a sound study. If CAT shows medical benefits, it may be integrated as part of a sensor-enhanced health information system and put into use [30, 31].

6. Conclusion

Our knowledge base and prototype implementation demonstrate the feasibility of telemedical decision support for physical training of COPD patients at home. The use of a standardized representation of the knowledge base, Drools and Arden Syntax, facilitates knowledge sharing and visualization. Our future work will focus on the evaluation of the software including the knowledge base in a clinical study.

References

1. Celli BR, MacNee W and committee members. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J 2004; 23: 932–946.
2. Fukuchi Y, Nishimura M, Ichinose M. COPD in Japan: the Nippon epidemiology study. Respirology 2004; 9: 458–465.
3. Murray CJL, Lopez AD. The global burden of disease: a comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020. Cambridge: Harvard University Press; 1996.
4. National Institutes of Health National Heart, Lung, and Blood Institute. Morbidity & Mortality: 2002 Chart Book on Cardiovascular, Lung, and Blood Diseases. 2002.
5. Konietzko N, Fabel H. White paper lung. Stuttgart-New York: Thieme press; 2000.
6. Nishimura S, Zaher C. Cost impact of COPD in Japan: Opportunities and challenges? Respirology 2004; 9: 466–473.
7. Chavannes N, Vollenberg JJH, van Schayck CP, Wouters EFM. Effects of physical activity in mild to moderate COPD: a systematic review. Br J Gen Pract 2002; 52 (480): 532–534.
8. Association of scientific medical societies. Diagnosis and treatment of patients with COPD. http://www.uni-duesseldorf.de/AWMF/ll/020-006.htm. Accessed April 3, 2008.
9. Murray JA, Waterman LA, Ward J, Baird JC, Mahler DA. Perceptual and physiological responses during treadmill and cycle exercise in patients with COPD. Chest 2008; 135 (2): 384–390.
10. Janos V, Janos P, Krisztina B, Richard C, Attila S. Supervised High intensity continuous and interval training vs. Self-paced training in COPD. Respiratory Medicine 2007; 101: 2297–2304.
11. Worth H, Meyer A, Folgering H, Kirsten D, Lecheler J, Magnussen H, Pleyer K, Schmidt S, Schmitz M, Taube K, Wettengel R. Empfehlungen der Deut-

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schen Atemwegsliga zum Sport und körperlichen Training bei Patienten mit obstruktiven Atemwegserkrankungen. [Recommendations of the German Airway League on sport and physical training in patients with obstructive airway diseases]. Pneumologie 2000; 54 (2): 61–67.
12. Marschollek M, Mix S, Wolf KH, Effertz B, Haux R, Steinhagen-Thiessen E. ICT- based health information services for elderly people: past experiences, current trends, and future strategies. Med Inform Internet Med 2007; 32 (4): 251–261.
13. Horwitz CM, Mueller M, Wiley D, Tentler A, Bocko M, Chen L, Leibovici A, Quinn J, Shar A, Pentland AP. Is home health technology adequate for proactive self-care? Methods Inf Med 2008; 47 (1): 58–62.
14. Volandes AE, Paasche-Orlow MK, Barry MJ, Gillick MR, Minaker KL, Chang Y, Cook EF, Abbo ED, El-Jawahri A, Mitchell SL. Video decision support tool for advance care planning in dementia: randomised controlled trial. BMJ 2009; 338: b2159.
15. Haux R; Howe J, Marschollek M; Plischke M, Wolf K-H. Health-enabling technologies for pervasive health care: on services and ICT architecture paradigms. Informatics for Health and Social Care 2008; 33 (2): 77–89.
16. Hermie JH, Miriam MR, Vollenbroek H. Towards remote monitoring and remotely supervised training. Journal of Electromyography and Kinesiology 2008; 18: 908–919.
17. Bardram JE. Pervasive healthcare as a scientific discipline. Methods Inf Med 2008; 47: 178–185.
18. Triantafyllidis A, Koutkias V, Chouvarda I, Maglaveras N. An open and reconfigurable wireless sensor network for pervasive health monitoring. Methods Inf Med 2008; 47 (3): 229–234.
19. Hein A, Nee O, Willemsen D, Scheffold T, Dogac A, Laleci GB. SAPHIRE – Intelligent Healthcare Monitoring based on Semantic Interoperability Platform – The Homecare Scenario. 1st European Conference on eHealth (ECEH'06), Fribourg, Switzerland, October 12–13, 2006.
20. Federal Institute for Sports Science. http://www.bisp-datenbanken.de. Accessed April 6, 2008.
21. Drools. Documentation Library. http://www.jboss.org/Drools. Accessed July 7, 2008.
22. Forgy CL. Rete: A fast algorithm for the many pattern/many object pattern match problem. Artificial Intelligence 1982; 19 (1): 17–37.
23. ANSI/HL7 Arden V2.5–2005. Health Level Seven Arden Syntax, Version 2.5 (revision of ANSI/HL7 Arden V2.1-2002). April 25, 2005.
24. Health Level Seven. http://www.hl7.org. Accessed November 3, 2008.
25. Tegtbur U, Meyer H, Busse MW. Belastungsdiagnostische Kenngrößen und Katecholamine bei Koronarpatienten. [Stress diagnostic characteristics and catecholamines in coronary artery disease patients]. Zeitschrift für Kardiologie 2002; 91 (11): 927–936.
26. Mediaportal. http://www.team-mediaportal.de. Accessed July 25, 2008.
27. Winter A, Brigl B, Wendt T. Modeling hospital information systems. Part 1: The revised three-layer graph-based meta model 3LGM2. Methods Inf Med 2003; 42: 544–551.
28. De Marees H. Sports physiology. Köln: Sport and Book Strauss Press; 2002.
29. Choi J, Lussier Y, Mendonca E. Adapting current Arden Syntax knowledge for an object oriented event monitor. AMIA Annu Symp Proc 2003; 2003. p 814.
30. Bott OJ, Marschollek M, Wolf K-H, Haux R. Towards new scopes: sensor-enhanced regional health information systems – part 1: architectural challenges. Methods Inf Med 2007; 46: 476–483.
31. Haux R. Expert systems in medicine. Habilitation thesis. Aachen technical university: Aachen, Germany; 1987.

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