Healthcare Delivery in the Information Age

Nilmini Wickramasinghe
Freimut Bodendorf *Editors*

Delivering Superior Health and Wellness Management with IoT and Analytics

Springer

Healthcare Delivery in the Information Age

Series Editor
Nilmini Wickramasinghe
Epworth HealthCare
Richmond, VIC
Australia

Swinburne University of Technology
Australia

The healthcare industry is uniquely structured so that the receiver of the services (the patient) often isn't the predominant payer for those services (the insurance company). Healthcare interventions are often complex and typically involve multiple players including providers, payers, patients and regulators. This leads to economic dilemmas such as moral hazard, information asymmetry, and tangential considerations of cost versus quality creating obstacles on the road to delivering efficient and effective healthcare. Relevant data, pertinent information, and germane knowledge play a vital role in relieving these problems and can be most effectively obtained via prudently structured and well designed healthcare technology. Some of the major challenges facing today's healthcare organizations include demographic (longer life expectancy and an aging population), technology (incorporating advances that keep people healthier), and financial (escalating costs technological innovation) problems. In order to realize technology's full potential it is imperative to understand the healthcare-technology paradigm, develop sustainability models for the effective use of technology in a specific context, then successfully design and implement patient-centric technology solutions. Many of the problems with technology are connected to the platform-centric nature of these systems which cannot support seamless transfer of data and information, leading to inferior healthcare delivery. This new series focuses on designing effective and efficient technologically enabled healthcare processes to support the delivery of superior healthcare and provide better access, quality and value. It's main goal will be to identify the barriers and facilitators in moving from idea generation to concept realization and will navigate the key challenges in the field: bringing readers solutions and recommendations while identifying key factors in developing technology-enabled healthcare solutions.

More information about this series at http://www.springer.com/series/8783

Nilmini Wickramasinghe • Freimut Bodendorf
Editors

Delivering Superior Health and Wellness Management with IoT and Analytics

Springer

Editors
Nilmini Wickramasinghe
Epworth HealthCare
Richmond, VIC
Australia

Swinburne University of Technology
Hawthorn, VIC, Australia

Freimut Bodendorf
Friedrich-Alexander-University
Erlangen-Nuremberg
Erlangen, Germany

ISSN 2191-5946 ISSN 2191-5954 (electronic)
Healthcare Delivery in the Information Age
ISBN 978-3-030-17346-3 ISBN 978-3-030-17347-0 (eBook)
https://doi.org/10.1007/978-3-030-17347-0

© Springer Nature Switzerland AG 2020
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

For Our Families

This Series is dedicated to Leo Cussen:
Learned scholar, colleague extraordinaire,
and good friend.

Foreword

The first mHealth Summit in Washington, DC, drew a mere 500 attendees in 2010, but it grew nearly tenfold after only 4 years. The initial products typically featured basic, consumer-facing health and wellness monitoring sensors, along with some of the earliest and simplest wrist-wearable activity sensors like the Fitbit.

The arrival of ubiquitous mHealth about a decade ago dovetails with unexpected and exceptional adoption of mobile communication technologies. One might easily forget that the iPhone and apps were only introduced in 2008, followed by the blockbuster introduction of the iPad in late 2009. Right behind the Apple products came a growing wave of Google Android-based cell phones and tablets, which greatly expanded the market. Simultaneously, broadband cellular and wi-fi services were also progressing rapidly, covering much broader geographic footprints with growing reliability and capacity.

As cell phones, apps, and cellular data services were growing quickly, IoT, though described in the research literature, had not yet become a generic product reality. Many/most mHealth products were, at that point, tethered to apps, and the phone/tablet devices became the store-and-forward tools. Mass manufacturing of low-cost IP-addressable wi-fi and cellular chips needed for phones and apps opened a new product opportunity, though: inexpensive stand-alone or clustered mHealth sensors that could be used to collect personal health data with or without smartphones or tablets. Sporadic and isolated islands of proprietary IP-addressable consumer-facing products were showcased in the 2015 Consumer Electronics Show, but they exploded into widespread deployment in 2017 after the Amazon Alexa and Google Assistant ecosystems began to consolidate the market.

In January 2019, the US Consumer Electronics Show showcased thousands of IoT-ready mHealth sensors, monitors, and health and wellness monitoring and management ecosystems. Many of the products displayed are also FDA-approved for life-critical medical care, not just wellness and fitness monitoring.

Despite all of the underlying technology progress, commercial adoption of IoT-based mHealth and eHealth technologies is still very slow. Yes, consumers are indeed purchasing a large variety of mHealth devices for personal and family use, but those devices are rarely used to communicate directly with physicians.

This book provides a diverse selection of chapters that shed light on many important theory, research, and practice that must be understood and resolved in order for the true opportunities of improved patient care access, better patient care coordination, higher patient and clinician adoption and satisfaction, and, ultimately, improved quality, safety, efficiency, efficacy, and cost-effectiveness of patient care and wellness management.

There are four overarching themes that organize this book's sections: mobile- and sensor-based solutions, opportunities to incorporate critical aspects of analytics to provide superior insights and thus support better decision-making, critical issues around aspects of IoT in healthcare contexts, and applications of portals in healthcare contexts.

The chapters are introduced well in the Preface, but a few of them stand out because they illustrate some of the interesting opportunities and challenges of IoT in healthcare applications.

The vast majority of chapters deal with the first mobile- and sensor-based solutions chapter, because the healthcare field is reaping the benefit of decades of sensor miniaturization and pervasive mobile connectivity research and product development from other industrial and consumer markets, e.g. automobiles, aircraft, drones, computer games, and smartphones have all been leveraging low-power microscopic gyroscope technologies for at least two decades, same with RFID chips, barcode readers, and location-based marketing which began to impact retail and manufacturing processes at about the same time.

The flood of new, lightweight, wearable, and wireless sensors is creating a rich choice of discrete patient data that only existed inside high-acuity hospital settings in the 1990s. This health data is being created 24 hours a day, year round, in settings ranging from home, school, allied health, physical fitness, sports, and vacation destinations. One need not look further than the latest Apple Watch Series 4 release in 2018, which offered FDA-approved atrial fibrillation ECG monitoring as an example.

In this book, "Towards a Tricorder . . . " and "Towards a Better Life for Diabetic Patients," chapters describe the aspirational goals of modern mobile health technology inventors. Other chapters illustrate novel ways for clinicians to collaborate more closely ("Piloting a Mobile Tele-Simulation Unit . . . " and "Mobile Nursing..."). Also, chapters like "SmartCoping . . . ," "Changing Behavior of Kids with Obesity . . . ," and "Precision wellness . . . " address the growing global interest to empower patients to manage their own wellness and healthcare with personalized tools that suit their health and lifestyle most effectively.

The section "Opportunities to incorporate critical aspects of analytics to provide superior insights and thus support better decision making" presents a number of novel ideas about translating the rapidly growing flood of mobile health data into information and knowledge for better decision, action, and outcomes. Notable chapters include these three: "Knowledge Acquisition of Consumer Medication Adherence," because medication errors are believed to cause the majority of preventable medical errors, harm, and expenses; "Data Quality in Healthcare," because ongoing flaws in mHealth data accuracy has greatly slowed widespread adoption and use of the technologies; and "Enabling Value-Based Health Care with Business Analytics and Intelligence" because of the global shift by government agencies away from financial incentives and profits as the primary lever to manage healthcare expenses.

The third section highlights some addition, "Critical Issues Around Aspects of IoT in Healthcare Contexts." The chapter on "Implementing Lean Principles in the Healthcare Industry . . . " points out novel constraints of healthcare, such as healthcare's "failures" being measured in lives lost, a far less forgiving metric than lost profits. The "AR/VR In Healthcare" chapter identified significant gaps in healthcare-related research versus applications in entertainment and other industries, and the "Data Disparity Denial" chapter delves into cost-, decision-, and responsibility-shifting that pervasive adoption of "best practices" can create for aging populations around the world who are exhibiting similar co-morbidities like obesity and diabetes which may greatly complicate or inhibit access to necessary therapeutic treatment like hip, knee, or cardiac valve replacement.

The fourth and final section sheds new light on "Applications of portals in healthcare contexts," because the emerging global model of health and wellness includes a very strong emphasis on "patient empowerment." The chapter on "Older Adults Empowerment Through Training and Support . . . " provides an excellent example, because it addresses the global phenomenon, challenge, and opportunity presented by rapidly growing elder populations. Similarly, the "Toward Actionable Knowledge . . . " chapter illustrates the opportunities that can emerge when patient self-care is integrated with physician/clinician tracking and intervention for improved patient-centric care. The "Determining missing key elements in OIS (Oncologic Information System) . . . " chapter does a very good job exposing information, communication, and collaboration gaps between patients, caregivers, and physicians when making decisions about cancer treatment pathways.

In summary, the rapidly expanding quantity of data becoming available from mobile IoT health and wellness devices is now beginning to lend itself to advanced analytic tools. These tools and techniques are often adopted and adapted from consumer and industry applications. For example, newly emerging artificial intelligence (AI) and machine learning (ML) tools are being used to strengthen proven generations of Business Intelligence and Analytics software from other industries, too. There are promising applications of these analytic tools to assist patients and clinicians for a number of chronic diseases like diabetes, where treatment pathways and care coordination practices have begun to converge. Such convergence improves the researchers', patients', managers', and clinicians' ability to derive actionable information from large population data sets. In addition, individual patients and clinicians can fine-tune the tools to better match specific and unique patient circumstances.

Today, the path forward remains unclear, and somewhat obscure, however. There are several factors that make mobile IoT healthcare applications quite novel and challenging. First, the healthcare industry is not homogeneous across specialties, nations, or societal subsets.

Healthcare practice does not follow rules like baseball or computer games. In fact, modern healthcare practices historically developed from clinical subspecialties that evolved along very disparate pathways over dozens, sometimes hundreds or thousands, of years. Second, diseases and co-morbidities (simultaneous diseases in the same patient) are rapidly increasing because human longevity has increased so rapidly in the past century. These co-morbidities can be very unique to the patient, based on history, heredity, and/or environmental factors. Third, the progression of one or multiple diseases, and the actual responsiveness to different medicines or therapy, varies from patient to patient, and the variation may evolve uniquely during daily circadian body rhythms and over the course of time. Fourth, and somewhat perversely, the underlying diseases are actively antagonistic and opportunistic, and many are found to effectively evolve, morph, relocate, and/or rapidly create defence mechanisms in response to medical interventions (e.g., some staphylococcus bacteria have evolved to the point where they are immune to virtually all modern antibiotics!).

The final issue, which has become sort of "the elephant in the room," is balancing personal health privacy and confidentiality against cost, convenience, and societal needs. To date, few IoT technologies have been developed with robust encryption and security in mind. Most commercial products rely more heavily on vendor's proprietary communication, storage, and analysis techniques. Not only aren't those systems inherently secured with typical SSL or encryption techniques, but such systems also limit government or hospital data collection, aggregation, and analysis (see the HITSP.org Technical Note 905 for a longer detailed discussion about underlying issues).

The original US government "consumer empowerment" electronic medical data standards were intentionally separated from the unfortunately named "biosurveillance" standards (see www.HITSP.org). "Biosurveillance" was intended as a catch-all umbrella for the societal benefit of tracking, identification, and remediation of high-risk health problems like infectious diseases, but the term also carries the stigma of potential government tracking of its own citizens and possible privacy intrusion threats to citizen safety. Because of the risk of governmental (or employer) access and misuse of personal health data, the noble goal of helping consumers access and control their own health data (consumer empowerment) added the shadow of doubt and privacy concerns by other HITSP standards regarding biosurveillance and newborn baby screening.

The ongoing pathetic failures of managing privacy via fines and criminal prosecution (https://ocrportal.hhs.gov/ocr/breach/breach_report.jsf) provide a painful reminder that such issues *must* be addressed in order to gain enduring traction and accelerated adoption of mobile IoT technologies.

Because privacy and security solutions are rapidly being explored and implemented in finance, retail, and other industries, the privacy and security of the global healthcare infrastructure should improve in the near future. Once that is solved, patient and citizen's data can be "de-identified," allowing much more acceptable integration with other population health data.

As the privacy, quality, and quantity of heterogeneous mobile IoT health data improves, the ideas, innovations, and opportunities that are described in this book's chapters will all contribute to the improvement, personalization, affordability, equity, and transformation of healthcare. Kudos to the authors and editors for assembling this timely and inspiring collection!

Villanova University
USA

Elliot B. Sloane

Preface

The *Internet of Things (IoT)* is made up of a network of devices all embedded with electronics, software, sensors, and connectivity to enable them to connect, interconnect, and exchange data (Brown 2016a, b; Internet of Things Global Standards Initiative; Hendricks 2015). This then creates further opportunities for direct integration of the physical world into computer-based systems which in turn results in efficiency gains, economic benefits, more effective operations, and typically a reduction in human labour (Vermesan and Friess 2013; Santucci 2016; Mattern and Floerkemeier 2016; Lindner 2015). In 2017, the number of IoT devices was over 8.4 billion (http://www.faz.net/aktuell/wirtschaft/diginomics/grosse-internationale-allianz-gegen-cyber-attacken-15451953-p2.html?printPagedArticle=true#pageIndex_1), and this is estimated to increase to 30 billion devices by 2020 (Nordrum 2016), while the global market value of IoT is anticipated to reach $7.1 trillion at this time (Hsu and Lin 2016).

IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of traditionally *dumb* or non-Internet-enabled physical devices and everyday objects (Hamid et al. 2019; Wigmore 2014; Internet of Things (IoT)). Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled (The “Only” Coke Machine on the Internet; Mattern and Floerkemeier2010; Weiser 1991; Magrassi and Berg 2002). Healthcare to date has been a laggard in embracing technology in general and the full extent of the potential of IoT specifically; however, this cannot continue if healthcare is to deliver superior patient-centred high-value care (Wickramasinghe and Schaffer 2010; Wickramasinghe et al. 2017).

Healthcare delivery in the twenty-first century is currently facing the triple challenge of exponentially increasing costs, aging populations, and the rise of chronic care (Wickramasinghe et al. 2017). This is leading most countries around the world to look at technology-enabled healthcare reform that provides better quality, better access, and better value care in general and leveraging the opportunities and benefits afforded by the technologies of the IoT for the healthcare domain (Wickramasinghe et al. 2017).

Our book serves to present a miscellany of papers which focus on critical aspects around embracing the technologies of the IoT to enable and support superior healthcare delivery and wellness management. This is still a very nascent domain and many issues around health literacy, policy, privacy, and security, not to mention the direct and subtle as well as far-reaching implications for the various stakeholders (patients, clinicians, healthcare organizations, regulators, payers, and the community at large) which have yet to be fully understood or identified.

Our goal is to simply compile the chapters to make up this work. We wanted to share with you, the reader, some of the critical touch points and help to enrich discussions and discourse and inspire further research into this critical domain, a domain that touches all of us, and thus, all of us should form considered opinions about its future directions. It is our belief that through the judicious use of the technologies of the IoT, it will indeed be possible to enable and sustain an environment where digital technologies support better monitoring, better data, better communications so that we have better access, better quality, and a high value of healthcare delivery and wellness management for all of us, when and how they need it.

The chapters making up this book have been arranged into four main sections as follows: (1) mobile- and sensor-based solutions, (2) opportunities to incorporate critical aspects of analytics to provide superior insights and thus support better decision-making, (3) critical issues around aspects of IoT in healthcare contexts, and (4) applications of portals in healthcare contexts.

Specifically, they are as follows:

Part I: Mobile and Sensor Based Solutions

- Chapter "Towards a Medical Tricorder – A 3D-Map to Categorize Diseases for Self-Care with Mobile Technology" by Hamper et al which describes an innovation challenge around designing a mobile IoT monitoring device to treat lifestyle cardiovascular and metabolic diseases and to enhance patient self-care.
- Chapter "Piloting a Mobile Tele-Simulation Unit to Train Rural and Remote Emergency Healthcare Providers" by Jewer et al. which discusses the development and piloting of a Mobile Tele-Simulation Unit (MTU) prototype to address the challenges of emergency healthcare training in rural and remote settings.
- Chapter "Drone Delivery for Medical Emergencies" by Scott, J and Scott C which provides a general overview of drone technology, and then explores ways drones can potentially improve emergency medical care by speeding delivery of medicines, devices, blood, vaccines, or even organs for transplant.
- Chapter "Converting Disability into Ability Using IT/IS and Smart Textiles" by Shaukat et al which focuses on utilizing IS/IT (Information Systems/Information technology) and smart textiles to empower individuals suffering from physical disability due to nerve/ neuron damage due to brain injury.

- Chapter "A Mobile Nursing Solution" by Kou et al. which discusses the design and development of a mobile nursing solution for medication management for a hospital in China.
- Chapter "SmartCoping: A Mobile Solution for Recognizing Stress and Coping With IT" by Reimer et al. which describes a mobile biofeedback app, SmartCoping, designed to recognize personal stress based on calibration to a person's unique heart rate variability (HRV).
- Chapter "Changing Behaviour Of Kids With Obesity With Gamification Wearables" by Schultz et al, which focuses on how gamification can be harnessed to assist with addressing childhood obesity.
- Chapter "Precision Wellness: An Optimization Model" by Cooper and Wickramasinghe which serves to differentiate between precision medicine, precision wellness and related terms and the role for the tools and technologies of IoT (Internet of Things).
- Chapter "The Development of a Wearable for an Automated Documentation and an Improved Staff Planning in Outpatient Care" by Ma and Weissenbaeck which presents a sensor-based solution to assist with assessing staff physical and psychological stress levels to assist with planning activities accordingly.
- Chapter "Toward a Better Life for Diabetic Patients – Developing and Integrating a Non-invasive Self-Management Support Tool Within a Smart Digital Companion" by Nguyen et al. which examines the potential for a non-invasive solution to assess blood glucose levels of individuals with diabetes.

Part II: Opportunities to Incorporate Critical Aspects of Analytics to Provide Superior Insights and Thus Support Better Decision Making

- Chapter "Intelligent Risk Detection in Health Care: Integrating Social and Technical Factors to Manage Health Outcomes" by Moghimi et al. which presents an integrative framework to support superior intelligent risk detection for various healthcare contexts.
- Chapter "A Literature Review on Predicting Unplanned Patient Readmissions" by Eigner and Cooney in which the authors examined the literature between 2005 and 2017 and found 44 relevant articles regarding predictive models for determining patient readmission factors.
- Chapter "Using Knowledge Management To Develop Superior Online Health Decision Support Solutions: The Case of Allergy Care" by Wickramasinghe presents a research in progress study that focusses on designing and developing a longitudinal knowledge base to track the progress and development of paediatric allergies.
- Chapter "Opportunities for Using Blockchain Technology in Ehealth: E-prescribing in Germany" by Seitz and Wickramasinghe which examines the potential for the incorporation of blockchain technology to support successful e-prescribing in Germany.
- Chapter "Knowledge Acquisition of Consumer Medication Adherence" by Vlahu-Gjorgievska et al which examines various analytical methods to assist with support better medical adherence.

Chapter “Addressing Data Accuracy and Information Integrity in Mhealth Solutions Using Machine Learning Algorithms” by Sako et al which present the potential of designing suitable machine learning algorithms to assist in identifying data accuracy levels in mhealth solutions.

Chapter “Enabling Value-Based Health Care with Business Analytics and Intelligence” by Wickramasinghe which presents the opportunities for leveraging BA (business analytics) and BI(business intelligence) capabilities into healthcare contexts for providing high value, patient centred quality care.

Part III: Critical Issues Around Aspects of IoT in Healthcare Contexts

Chapter “A review of Mixed Reality in Health Care” by John and Wickramasinghe which presents opportunities for Augmented reality, mixed reality and virtual reality solutions to be incorporated into various healthcare contexts to support a better patient experience and/or assist clinicians and clinical training.

Chapter “Implementing Lean Principles in the Healthcare Industry: A Theoretical and Practical Perspective” by Pakdil et al which presents the case for the benefits of incorporating lean principles into various healthcare technology implementations to enable the full realisation of the benefits afforded by the technology solutions.

Chapter “Data, Denial, and Disparity: Is This a New Digital Divide” by Wickramasinghe et al which examines the potential negative impacts of a technology enabled value-based care imitative that fails to recognise challenges and realities for vulnerable groups in the community.

Chapter “The Enabling Role for Technology in the Support of Care Coordination in Health Care” by Gibbings and Wickramasinghe which presents the merits of adopting a technology enabled care co-ordination vision for delivery superior patient-centred care.

Chapter “Managing the Risks of Emerging IoT Devices” by Paxton and Branca which provides insights on how to ensure suitable cybersecurity safe guards are in place when using IoT devices in healthcare contexts.

Chapter “Mosquitoes and Public Health: Improving Data Validation of Citizen Science Contributions Using Computer Vision” by Muñoz et al. which highlights important public health impacts and how IoT can potentially assist.

Part IV: Applications of Portals in Healthcare Contexts

Chapter “Using Responsive Web Design to Enhance the User Experience of Chronic Disease Management Portals for Clinical Uses” by Gunawardane and Wickramasinghe which highlights the need to design suitable web interfaces so that solutions load equally gracefully on computers, handheld devices and tablets for an optimal user experience.

Chapter “Older Adults Empowerment Through Training and Support and Its Implication on Proactive Self-Monitoring, Patient Engagement, and Connected Health” by Bozan and Mooney which discusses the benefits of training and support especially for older adults in regards to technology solutions and their effective adoption and use.

Chapter "An Evaluation of a Point-of-Care (PoC) System Implementation and Adoption in a Multi-Campus Private Hospital in Melbourne" by Muhammad and Wickramasinghe which examines the adoption and implementation of the OneVeiw Poitn-of-C-are systems into a private not for profit tertiary healthcare system in Melbourne, Australia.

Chapter "Leveraging the IOT to Enable the Guided Self-Determination Method" by Wickramasinghe et al. which examines the repurposing of the Guided Self-Determination (GSD) method into the Australian healthcare context.

Chapter "Determining Key Elements in Oncology Information System to Improve the Patient Experience and Clinical Care" by Shaukat et al. which examines several OIS (oncology information system) solutions to assess their strengths, weaknesses and key barriers and facilitators.

Chapter "Toward Actionable Knowledge: A Systematic Analysis of Mobile Patient Portals" by Noteboom and Abdel-Rahman which investigates and then identifies critical issues around designing suitable patient portals.

Chapter "A Lazy User Perspective to Patient Adoption and Use of Personal Health Records" by Kunene which examines critical issues around personal health records and patients portals.

Chapter "The Australian PCEHR OR My Health Record – The Journey Around a Large Scale Nationwide Digital Health Solution" by Wickramasinghe and Zelcer which traces key design and development and deployment of the national eHealth solution adopted by Australia.

No book can ever present in one volume a comprehensive collection covering all areas of IoT for healthcare; however, we hope this miscellany of chapters we present will challenge our readers and be thought provoking. We also hope that you have as much fun reading our book as we have had in compiling and writing it. In closing, we trust that on the completion of this book, researchers, scholars, practitioners, consultants, and the general public will all have a better understanding of how the technologies of the IoT can be harnessed to provide superior healthcare delivery and wellness management and will rise to the challenge of starting to build a better health and wellness environment for tomorrow and today.

East Kew, VIC, Australia — Nilmini Wickramasinghe
Nürnberg, Germany — Freimut Bodendorf
September 2019

References

Brown, E. (2016, 13 September). *Who needs the Internet of Things?*. Linux.com. Retrieved 23 October 2016.

Brown, E. (2016, 20 September). *21 open source projects for IoT*. Linux.com. Retrieved 23 October 2016.

Hamid, U. Z. A., et al. (2019). Internet of Vehicle (IoV) applications in expediting the implementation of smart highway of autonomous vehicle: A survey. Performability in Internet of Things. Retrieved 28 August 2018.

Hendricks, D. (2015). *The trouble with the Internet of Things*. London Datastore. Greater London Authority. Retrieved 10 August 2015.

Hsu, C.-L., & Lin, J. C.-C. (2016). An empirical examination of consumer adoption of Internet of Things services: Network externalities and concern for information privacy perspectives. *Computers in Human Behavior*, *62*, 516–527. https://doi.org/10.1016/j.chb.2016.04.023.

http://www.faz.net/aktuell/wirtschaft/diginomics/grosse-internationale-allianz-gegen-cyber-attacken-15451953-p2.html?printPagedArticle=true#pageIndex_1

Internet of Things (IoT). gatewaytechnolabs.com.

Internet of Things Global Standards Initiative. ITU. Retrieved 26 June 2015.

Lindner, T. (2015, 13 July). *The supply chain: Changing at the speed of technology*. Connected World. Retrieved 18 September 2015.

Magrassi, P., & Berg, T. (2002, 12 August). A world of smart objects. Gartner research report R-17-2243.

Mattern, F., & Floerkemeier, C. (2010). From the internet of computer to the Internet of Things (PDF). *Informatik-Spektrum*, *33*(2), 107–121. https://doi.org/10.1007/s00287-010-0417-7. Retrieved 3 February 2014.

Mattern, F., & Floerkemeier, C. (2016). *From the internet of computers to the Internet of Things (PDF)*. ETH Zurich. Retrieved 23 October 2016.

Nordrum, A. (2016, 18 August). *Popular Internet of Things forecast of 50 billion devices by 2020 is outdated*. IEEE.

Santucci, G. (2016). *The Internet of Things: Between the revolution of the internet and the metamorphosis of objects(PDF)*. European Commission Community Research and Development Information Service. Retrieved 23 October 2016.

The "Only" Coke Machine on the Internet. Carnegie Mellon University. Retrieved 10 November 2014.

Vermesan, O., & Friess, P. (2013). *Internet of Things: Converging technologies for smart Environments and Integrated Ecosystems (PDF)*. Aalborg, Denmark: River Publishers. ISBN 978-87-92982-96-4.

Weiser, M. (1991). The computer for the 21st century (PDF). *Scientific American*, *265*(3), 94–104. Bibcode:1991SciAm.265c..94W. https://doi.org/10.1038/scientificamerican0991-94. Archived from the original (PDF) on 11 March 2015. Retrieved 5 November 2014.

Wickramasinghe, N., & Schaffer, J. (2010). *2010 realizing value driven patient centric healthcare through technology*. IBM Center for the Business of Government, DC.

Wickramasinghe, N., Johns, B., George, J., & Vogel, D. (2017). Achieving value-based care in chronic disease management: The DiaMonD (Diabetes monitoring) solution. *JMIR Diabetes forthcoming.*

Wigmore, I. (2014, June). Internet of Things (IoT). TechTarget.

Acknowledgements

This work would not be possible without the support and contributions of many people, too numerous to name individually. First and foremost, we thank all the authors who have contributed such thought-provoking chapters that fill the following pages. We are indebted to our respective institutions for affording us with the time to work on this book project. In addition, we are most grateful to the wonderful assistance provided by the team at Springer, especially Janet Kim. Finally, we thank our families for their ongoing support.

Professors Nilmini Wickramasinghe and Freimut Bodendorf, December 2018

Contents

About the Editors

Nilmini Wickramasinghe is the inaugural Professor-Director, Health Informatics Management, at Epworth HealthCare and the Professor of Digital Health and Deputy Director of the Iverson Health Innovation Research Institute at Swinburne University as well as an Honorary Professor at the Peter MacCallum Cancer Centre. After studying at the University of Melbourne, she accepted a full scholarship to undertake PhD studies in the United States in Management of Information Systems as they relate to healthcare contexts. For over 20 years, she has been actively researching and teaching within the health informatics domain. Her particular focus is on designing and developing suitable models, strategies, and techniques grounded in various management principles to ensure that technology solutions effect superior, value-based, patient-centric care delivery. He collaborates with leading scholars at various premier healthcare organizations throughout Australasia, the United States, and Europe and has well published with more than 380 refereed, peer-reviewed scholarly articles, more than 12 books, numerous book chapters, an encyclopaedia, a patent, and a well-established funded research track record. He is the Editor-in-Chief of two scholarly journals published by Inderscience and has successfully taken four separate health technology solutions from idea to realization in the United States.

Freimut Bodendorf is Head of the Chair of Information Systems (Services, Processes, Intelligence) and Director of the Institute of Information Systems. He graduated from the University of Erlangen-Nuremberg (School of Engineering) with a degree in Computer Science. He obtained his doctor degree (PhD) in Information Systems. Subsequently, he was Head of an IS Department at the University Hospital and Medical School at the University of Freiburg, Germany; Professor at the Postgraduate School of Engineering in Nuremberg, Germany; and Head of the Department of Computer Science and Information Systems at the University of Fribourg in Switzerland. Actually, he is Director of the Institute of Information Systems at the University of Erlangen-Nuremberg and Faculty Member of the School Business and Economics as well as the School of Engineering. His research areas include service design and engineering, process management, and business intelligence. Current projects investigate and create solutions in the fields of healthcare, commerce/retail, industrial services (smart factory and supply), and education.

About the Authors

Mohammad Abdel-Rahman (Al-Ramahi) is an Assistant Professor of CIS at the Department of Computing and Cyber Security, Texas A&M University, San Antonio. His research appears in the *ACM Transactions on Management Information Systems* journal. He also has published several refereed conference papers in the areas of text mining and IS design.

Sasan Adibi is a Lecturer in the School of Computer Science at Deakin University. He has interests in designing and developing technology solutions for various healthcare contexts.

Monica Adya is Professor of Management at Marquette University. Her research addresses knowledge-based systems with applications to business forecasting and IS workforce issues. She has published in *Communications of the Association for Information Systems*, *Decision Support Systems*, *Human Resource Management*, *Information Technology & People*, *International Journal of Forecasting*, and *Information Systems Research* among others.

Karoly Bozan is an Assistant Professor of Information Systems Management at Duquesne University. He spent over a decade as the Technical and Management Consultant before returning to academia. His research interests are technical empowerment of the elderly, health informatics, and digital innovations.

David L. Branca is the Director of Research and Development at IOMAXIS, LLC. He holds an MS degree from SUNY ESF and a BS degree from RIT. He is active in the research and application of securing IoT and containers, of which he holds five cyber security patents.

Andrew Cooney studied Information Systems at the University of Erlangen-Nuremberg. In 2017, he did his master thesis on readmission risk prediction at the Institute of Information Systems.

Paul Cooper, PhD, FACHI, CHIA specializes in health informatics management and teaches on this topic at Deakin University. He obtained a PhD at the Walter and Eliza Hall Institute of Medical Research (Melbourne University), BSc (Monash

University), and a Grad Dip Business (Organisational Development) at RMIT University.

Judy Currey is the Director, Active Learning, at Deakin University. Her research is focused on decisions that impact patient safety and quality of care. She is a qualified Team-Based Learning Consultant-Trainer and has been awarded numerous national and local teaching and innovation awards. She is a graduate of the AICD.

S. A. Sjoerd de Vries is Assistant Professor at the University of Twente, Enschede, Netherlands. His research is in the field of digital transformations in the public sector. His focus is on the development, adoption, and implementation of data-driven and currently AI-based services.

Adam Dubrowski obtained his PhD from the University of Waterloo in 2001. In 2002, he joined the University of Toronto and in 2013 the Memorial University of Newfoundland. He began his research career by studying factors that influence the acquisition, maintenance, and transfer of skills. More recently, his research has focused on the role of disruptive innovations, such as 3D printing and virtual reality in training healthcare professionals. He has worked with a wide scope of professionals including kinesiologists, physiotherapists, surgeons, paediatricians, emergency physicians, and nurses. The unifying theme of his work is the use of simulation for education and training, assessment, and patient safety.

Cody Dunne holds a Bachelor of Science degree from the Memorial University of Newfoundland and is currently a Doctor of Medicine (MD) candidate at this institution. His research interests focus on the use of simulation for the training of healthcare professionals and lay-rescuers.

Isabella Eigner studied International Information Systems at the University of Erlangen-Nuremberg. Since 2014, she is a Member of the research staff and PhD student at the Institute of Information Systems. In her research, she is focusing on predictive analytics in healthcare.

Rima Gibbings has worked as a System Designer and Developer in healthcare systems and has a PhD from the University of Illinois in Chicago. As a Health Informatics Specialist and Researcher, she offers a technical approach that links her background in application development with public health topics, addressing current technical requirements.

Ranganath Gunawardane received his bachelor's degree in Electronics from the University of Peradeniya, Sri Lanka. He has more than 14 years of professional experience in the field of information technology. He is also a Research Affiliate at Epworth HealthCare.

Andreas Hamper completed his PhD at the Friedrich-Alexander-University Erlangen-Nuremberg under the Chair of Information Systems. His focus is on mobile and sensors and their applications to health and wellness management.

Timothy N. Harwood is an Associate Professor of Anesthesiology and Departmental Director of Quality Improvement in the Department of Anesthesiology at Wake Forest University Health Sciences in Winston-Salem, NC, USA. He attended medical school at the University of Missouri-Columbia and residency at Indiana University School of Medicine in Indianapolis, IN.

Harith Hassan completed Master of Information Technology Advanced in 2017 from the University of Wollongong majoring in ICT Strategic Planning and Enterprise Networking. During his studies, he has a special interest in health informatics and conducted research on medication adherence.

Kristopher Hoover received a Bachelor of Engineering degree from the Memorial University of Newfoundland in 2018. His research interests are focused in the areas of holistic frameworks for medical technology development and simulation modalities for healthcare education. He intends to continue exploring these areas while studying Medicine at the Memorial University of Newfoundland.

Feride Bahar Isin is an Associate Professor of Management at the Faculty of Economics and Administrative Sciences, Baskent University, in Turkey. She has an MBA degree from Baskent University and a PhD degree from Gazi University, Turkey. Her research interests are consumer behaviour and services marketing.

Jennifer Jewer holds a MASc and a PhD in Management Sciences from the University of Waterloo. She is an Assistant Professor in Information Systems in the Faculty of Business Administration at the Memorial University of Newfoundland. Her research focuses on the management and use of IT in organizations, and her recent projects have been in healthcare settings. She has a diverse range of consulting experience in risk management and software development.

Blooma John is a Lecturer at Canberra University, Australia. She completed her PhD from Nanyang Technological University (NTU), Singapore. Her research interest is in the area of text mining, question answering services, and healthcare social media. Her research has been published in journals such as the *Online Information Review*, *IEEE Internet Computing* and *Computers & Education*. She has published in various international conferences. She also has international experience in teaching leading information systems and business analytics courses in the Middle East, Singapore, India, and Vietnam at both undergraduate and postgraduate level.

Lars Kayser, MD, PhD is a Board-Certified Specialist in Internal Medicine and has worked for the last 10 years in the field of innovation and informatics in healthcare. He has helped develop the Epital Care Model, as well as the eHealth literacy framework, and eHealth literacy questionnaire.

Jianqiu Kou is a PhD student of Deakin University, Australia, and has 20 years of working experience in the field of construction and management of information systems in healthcare institutions. Her main research interests lie in the application of information technology in healthcare field.

K. Niki Kunene is an Assistant Professor of Information Systems at Eastern Connecticut State University. Her research interests include the design, use of patient engagement tools for health outcomes, and information privacy. She's also published on decision support/data mining methods in healthcare and business applications.

Edith Maier has a background in social anthropology and information science and joined the University of Applied Sciences, St. Gallen, in 2003. Her research focuses on intercultural factors in human-computer interaction as well as behavioural change support systems, mainly in digital health.

Michael J. McCoy has had multiple executive roles in the healthcare information technology and interoperability world, consulting, and provider organizations such as CMIO and as the first Chief Health Information Officer for the Office of the National Coordinator for Health Information Technology (ONC). He is Co-Chair of IHE International, representing HIMSS.

Hoda Moghimi, PhD, MSc, BEng received her PhD from RMIT University, Australia. She operates and researches within the information systems domain including business analytics, data science, knowledge discovery, IT and governance, intelligent solutions, and smart systems. She's published over 30 peer-reviewed scholarly journal and conference papers as well as book chapters in information systems.

David Mooney is a graduate student at The Ohio State University and has an extensive industry experience in the health and engineering domain. He has been consulting internationally while performing academic research.

Imran Muhammad, PhD, MIS, MBus (ERP Systems) is a Lecturer at the School of Medicine, Deakin University, Melbourne. He has a broad range of research interests in the areas of management information systems, health information systems, and electronic health records and cross-cultural system implementations and adoptions.

Lucas Neitzel is a higher degree candidate at the Friedrich-Alexander-University Erlangen-Nuremberg under the Chair of Information Systems. His focus is on analytics in health and wellness.

Lemai Nguyen is an Associate Professor at the Department of Information Systems and Business Analytics, Deakin University (Melbourne Campus). She actively conducts research and publishes in information systems (IS) areas including health informatics, business requirement analysis, and business information systems. She has published widely in many international scholarly journals, book chapters, and fully refereed conferences of high-quality (ERA ranking A and B).

Cherie Noteboom, PhD is an Associate Professor of Information Systems in the College of Business and Information Systems at Dakota State University. She has extensive experience in information systems, healthcare, and leadership. She has refereed publications in variety of IS fields. She is an active Member of PMI, ACM, HIMSS, and AIS.

Fatma Pakdil is an Associate Professor of Management at Eastern Connecticut State University in CT, USA. She has a BS degree in Econometrics and MBA and PhD degrees in Management from Uludag University in Turkey. Her research interests are quality control, service quality, lean production, Six Sigma, and healthcare management.

Michael Parsons, MD, CCFP (EM), FCFP is an ER Physician who completed his EM Fellowship at the Memorial University of Newfoundland in 2007. He is Chair and Assistant Professor in the Discipline of Emergency Medicine, with a cross-appointment to the Discipline of Family Medicine. He currently serves as the Assistant EM Programme Director at the Memorial University of Newfoundland. His teaching interests focus on simulation, procedural skills training, toxicology, and point-of-care ultrasound. Ongoing research activities are focused on the delivery of simulation-based teaching to rural and remote areas through mobile tele-simulation.

Napoleon C. Paxton is the Director of Innovation at IOMAXIS, LLC. He holds a PhD from The University of North Carolina at Charlotte in Information Technology, concentrating in cyber security. He also has over 20 publications including 2 book chapters and holds 1 patent in cyber security.

Bodil Rasmussen research focuses to improve the quality of care and self-management in people with diabetes and complex conditions. Her research programme focuses on empowering people to self-manage their condition by using technologies and implementation of research evidence into practice to improve patient outcomes; numerous projects involve international teams.

Ulrich Reimer has a background in computer science and has been with the University of Applied Sciences, St. Gallen, since 2005. His research activities concern mobile health applications to support individuals in changing their behaviour to improve their health. This includes data mining approaches to make sense of sensor data.

Zaid Sako is a Master student who is focused on doing research around health informatics issues, in particular focusing on Big Data and healthcare.

Jonathan L. Schaffer, MD, MBA is Managing Director of the Distance Health team in the Office of Clinical Transformation and of eClevelandClinic in the Information Technology Division at Cleveland Clinic. He leads the MyConsult programme, an online second medical opinion programme that is used by consumers and corporations worldwide to provide access to care while removing the geographic barriers. He also leads the DrConnect series of portals which securely connect referring physicians, facilities, and external reviewers to their patient's care at Cleveland Clinic. An active Board-Certified Joint Replacement Surgeon, Dr. Schaffer is also a Staff Member in the Center for Joint Replacement in the Orthopaedic and Rheumatologic Institute where he is the Physician champion on the ICD-10 transition and leads the Advanced Operative Technology Group, developing novel technologies for the arthroplasty patient population including the physical and technology upgrading of the operating rooms.

Luisa Schulz (1990) is a Digital Healthcare Enthusiast with an academic background in innovation management and healthcare innovation. She has an international background and completed an MBA at the University of Twente and an MSc in Innovation Management and Entrepreneurship at the Technical University of Berlin. She lives and works in Berlin where she has gathered professional consulting experience in the pharma und healthcare industry. As she has specialized in healthcare, she dedicates her research to the area of digital health.

Carlton H. Scott is Professor of Operations and Decision Technologies at the University of California, Irvine. He specializes in optimization models for managerial decision-making. He has more than 100 articles in research journals that look at both theory and application of optimization models. Application papers cover diverse areas such as the harvesting of sugar cane, assignment of customers to a commercial satellite fleet, the sizing of blind fasteners for construction purposes, and the recycling of electronic components.

Judy E. Scott, PhD is an Associate Professor of Information Systems at the University of Colorado Denver. She received her PhD and MBA from the University of California at Irvine. Her research interests include information technology in healthcare, knowledge management, and analytics capability for decision-making. Her journal publications include the *Journal of Management Information Systems*, *Information and Management*, *Decision Support Systems*, *Information Systems Frontiers*, *MIS Quarterly Executive*, and *Communications of the ACM*. She serves on the Editorial Board of *MIS Quarterly Executive*, *Information Systems Management*, and the *International Journal of Strategic Information Technology and Applications*.

Juergen Seitz received his PhD from Viadrina European University, Frankfurt (Oder), Germany. He is Professor of Business Information Systems and Head of the Business Information Systems Department at Baden-Wuerttemberg Cooperative State University Heidenheim, Germany. He is Editor, Associate Editor, and Editorial Board Member of several international journals.

Muhammad Nadeem Shaukat achieved his BEng in 2001 from the University of Engineering and Technology, Lahore, Pakistan. He served as Research and Development Engineer at Faisal Spinning Mills and Blessed Textile Mills Ltd. from 2001 to 2004. He joined National Textile University, Faisalabad, as a Faculty Member in 2004 and meanwhile supervised a number of research and industrial projects. He completed his master’s degree in Fibre and Polymer Engineering in 2009, from Hanyang University, Seoul, South Korea. He received his PhD in Nanotechnology from Deakin University, Australia. His research interests include nanotechnology, modelling, sensors, information technology, and healthcare.

J. B. Silvers, PhD is the John R. Mannix Medical Mutual of Ohio Professor of Health Care Finance and Professor of Banking and Finance at the Weatherhead

School of Management with a joint appointment in the Case Western Reserve University School of Medicine. His research in the areas of financial management and health services has been published in numerous journals including *The Journal of Finance*, *Financial Management*, *Journal of the American Medical Association*, *Medical Care*, *The Annals of Family Medicine*, the *Journal of Business Research*, *Journal of Consumer Marketing*, and *The New York Times*, MarketWatch, Crain's Cleveland Business, and others. Frequently, he contributes commentary to NPR's Marketplace and other national and local print and broadcast media.

Elliot B. Sloane has spent over 40 years in a dual career spanning IT and medical technologies that improve healthcare. He is also an Advisor and Consultant to several US federal agencies and the World Health Organization. Today, he is the Director of Drexel University's Health Systems Engineering Program in Philadelphia and is developing courses and research programmes in healthcare informatics, medical device interoperability, patient data and security, mobile healthcare, RFID in healthcare, and related fields. He also leads a non-profit Center for Healthcare Information Research and Policy (CHIRP), to assure the next generations of health IT products and services are truly patient-centric, safe, efficient, and effective.

Andrew Smith is a Family/ER Physician and Associate Professor at the Memorial University of Newfoundland with 10 years of clinical experience. Prior to Medicine, he completed a master's degree in Electrical Engineering. Presently, he is working to develop a formal biomedical engineering programme at the university and a medical technology sector for the province of Newfoundland and Labrador.

A. A. M. Ton Spil (1964) teaches in the area of business information systems for MBA and risk management and business and IT. He did his PhD thesis on the effectiveness of information strategies, and after that, he specialized in the area of healthcare application and professional organizations. He is e-health Track Chair in main conferences and published on ISI A level. He was (Guest) Editor of *JSIS* and Associate Editor of several health journals. In 2017, his main topics are adoption of IT, business modelling, serious gaming, and digital strategies applied on (tele) health, music, and banking. He creates digital strategies for (social) media and health. His new book is called *Digital Future* which appears in May 2018.

Tom Ulmer has been a Lecturer at the University of Applied Sciences, St. Gallen, since 2015. Before joining academia, he worked as a Product Manager and Software Architect with a focus on tracking and monitoring vital data for developing personalized health applications. This is now his main research focus.

Elena Vlahu-Gjorgievska received her PhD from the Faculty of Computer Science and Engineering at the "Ss. Cyril and Methodius" University in Skopje, in 2013. From 2007, she was working at the Faculty of Information and Communication Technologies, Sofia University "St.Kliment Ohridski" in Bitola, Macedonia. Currently, she is a Lecturer in the School of Computing and Information Technology, Faculty of Engineering and Information Sciences, at the University of Wollongong, Australia. Her research interests include information systems and ehealth. She has published over ten papers in international journals and presented her work at several conferences.

Khin Than Win is Associate Professor at the School of Computing and Information Technology. As a medical doctor conducting health informatics research, she brings a wealth of clinical knowledge in information systems and health informatics research. Her research is in persuasive technology, IT-assisted health education, behavioural change support systems, health data analytics, information security in healthcare, and electronic health record systems. She is also a Director of the Centre for Persuasive Technology and Society at the University of Wollongong. She has published widely in health informatics and obtained competitive grants such as Australian Research Council Grant.

John Zelcer MB, BS, BMedSc (Hons), FANZCA, MAICD, CHIA is a Company Director, Corporate Strategy Advisor, Informatician, and Executive Coach whose passion and focus is helping organizations, executive leaders, and leadership teams generate outstanding results for all their stakeholders, particularly in the healthcare sector. His career has spanned clinical and academic medicine in Australia and the United States, including a Visiting Professor role at Stanford University in California and currently as an Adjunct Professor in the School of Medicine at Deakin University, Australia. He has also held strategy management consulting and senior executive management roles in both Australia and the United States. His business roles have included board chairmanship, board directorship, and senior executive roles in strategic planning and business development.

Qianqian Zhang has a master's degree major in Biomedical Engineering. She has 5 years of working experience in biobank information system construction and bioinformatics analysis. Her research interests and directions are the application of information technology, precision medicine, and molecular diagnosis in clinical practice.

Vibeke Zoffmann is a Professor at the University of Copenhagen and Rigshospitalet, JMC. She has developed theories and methods around PROM in translational empowerment. She has developed an analogue guided self-determination (GSD) in chronic conditions, digitized together with Sundhed.dk, the Danish national health platform, and being disseminated through GSD blended learning developed together with CHR in Copenhagen.

Part I
Mobile and Sensor-Based Solutions

This section consists of 10 chapters as follows:

Chapter 1: Towards a Medical Tricorder: A 3D-Map to Categorise Diseases for Self-Care with Mobile Technology by Hamper et al.
Chapter 2: Piloting a Mobile Tele-simulation Unit to Train Rural and Remote Emergency Health-Care Providers by Jewer et al.
Chapter 3: Drone Delivery Models for Medical emergencies by Scott, J and Scott C.
Chapter 4: Converting Disability into Ability Using IT/IS and Smart Textiles by Shaukat et al.
Chapter 5: A Mobile Nursing Solution by Kou et al.
Chapter 6: SmartCoping: A Mobile Solution for Recognizing Stress and Coping with IT by Reimer et al.
Chapter 7: Changing Behavior of Kids with Obesity with Gamified Wearables by Schultz et al.
Chapter 8: Precision Wellness: An Optimization Model by Cooper and Wickramasinghe
Chapter 9: The Development of a Wearable for an Automated Documentation and an Improved Staff Planning in Outpatient Care by Ma and Weissenbaeck
Chapter 10: Towards a Better Life for Diabetic Patients: Developing and Integrating a Non-invasive Self-Management Support Tool Within a Smart Digital Companion by Nguyen et al.

Taken together, these chapters enable us to begin to understand the potential and possibilities for mobile and sensor solutions to assist individuals and/or groups in the community to address specific health and wellness issues from chronic conditions to better medical adherence. As you read these chapters, it is useful to consider what it is about these solutions that make them successful and embraced by users. All these solutions are suitable because they exhibit key technology, process, and people requirements. Succinctly the technology components work and are at an appropriate level of accuracy and fidelity above standard solutions; the solutions simplify and streamline processes, and they are easy to use and patient/user centered. Hence, what we see is that successful mobile solutions need to have sound technical and clinical outcomes as well as support patient and clinical user needs. The potential and possibilities for incorporating mobile and sensor solutions into the health and wellness domain is only limited to our imagination, but getting these solutions right, adopted and ensuring that they do indeed enable superior patient-centered superior value-based care to result is more challenging.

Towards a Medical Tricorder: A 3D Map to Categorise Diseases for Self-Care with Mobile Technology

Andreas Hamper, Lucas Neitzel, Nilmini Wickramasinghe, and Freimut Bodendorf

1 Introduction

The extensive spread of information and mobile technologies in the field of consumer electronics assists individuals in numerous areas. Health and fitness applications, fitness trackers and wearables show particularly high, sustained demand among private consumers. Highly efficient and cost-effective digital consumer electronic sensor technologies can also be used for medical purposes. Non-invasive technologies offer capabilities to detect, measure and analyse medical conditions by private consumers.

The increase in so-called civilization diseases has been recorded in industrialised countries such as Germany for many years (Robert Koch-Institut 2015b). Lifestyle-related cardiovascular diseases and metabolic disorders, such as diabetes, are problems which are growing rapidly (World Health Organization 2016b). The number of adults suffering from diabetes has risen worldwide from 108 million in 1980 to an estimated total of 422 million in 2014. This corresponds to an increase of 390% since 1980 (World Health Organization 2016c).

At the same time, self-care is increasing as well. The WHO defines self-care as "[. . .] the ability of individuals [. . .] to promote health, prevent disease, and maintain health and to cope with illness and disability with or without the support of a health-care provider" (World Health Organization 2009, p. 17). The raising awareness of self-care can be seen in the growing sales volume of fitness applica-

A. Hamper · L. Neitzel · F. Bodendorf
FAU Friedrich-Alexander-University of Erlangen-Nuremberg, Nuremberg, Germany

N. Wickramasinghe (✉)
Epworth HealthCare, Richmond, VIC, Australia

Swinburne University of Technology, Hawthorn, VIC, Australia

© Springer Nature Switzerland AG 2020

N. Wickramasinghe, F. Bodendorf (eds.), *Delivering Superior Health and Wellness Management with IoT and Analytics*, Healthcare Delivery in the Information Age, https://doi.org/10.1007/978-3-030-17347-0_1

tions for smartphones and fitness trackers in the field of consumer electronics. The core objective of these is to track and monitor vital parameters mainly for sports-related reasons (GfK SE 2016). Continuously increasing measuring accuracy and technical performance also makes non-invasive mobile technologies attractive to the medical sector.

With the evaluation of current technologies, a growing number of medical conditions, especially vital signs and lifestyle-related cardiovascular diseases, can be identified and monitored easily, precisely and non-invasively by consumers. This is of particular significance, given that consumer electronic technologies can no longer be seen only as a complementary element besides professional medical procedures but are increasingly able to provide medical diagnoses and monitor diseases without the help of medical experts. This implies that low-cost consumer electronic technologies empower consumers to better monitor their health and promote individual self-care in the near future.

Companies such as Google are already working towards products which could be used for medical purposes in the near future ("Digital Contact Lenses Can Transform Diabetes Care" 2016). Prizes for innovations in mobile health technologies and medical tricorders for the consumer electronics area are being offered. Particular commitment is shown by Qualcomm's XPRIZE. The prize was announced in 2013 and is endowed with USD 10,000,000. The aim of this prize is to develop a medical tricorder which will be able to detect a preselected set of vital signs and diseases non-invasively (XChallenge 2014; XPrize 2016).

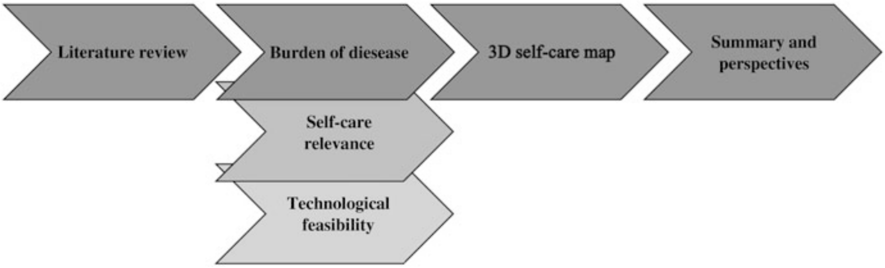
Following the example of the XPRIZE, a preselected set of vital signs and health conditions will be examined in this chapter. The burden of disease will be determined using public health reports and medical journals as well as epidemiological measurement concepts. Furthermore, we analyse to what extent these diseases are lifestyle-related. Mainly lifestyle-related diseases have a higher self-care relevance since individuals could actively affect these medical conditions. Consumer Technologies are screened whether they are suitable for non-invasive or mainly non-invasive measurements of the predefined vital signs and diseases. Therefore, it should be possible for consumers to use these technologies independently without external help if possible, in order to promote self-care. The scope lies on accessible and easy-to-use technologies, which are open to the public and are already on the market or may come into the market in the near future.

The goal of the chapter is to evaluate suitable, non-invasive technologies for the measurement of medical conditions and to examine how these technologies may improve consumer self-care, especially in the field of lifestyle-related diseases.

The following methodical procedure is used to create a 3D self-care map to guide the development of mobile technologies for healthcare (Graph 1).

In the first step, essential terms and the theoretical medical background of selected conditions are described though a short literature review.

On this basis, the burden of disease is determined for each condition with the aid of quantitative epidemiological data such as incidence and prevalence rates. These serve as yardsticks for the classification of the burden of disease (Department of Health New York State 1999; Pai and Filion 2003).



Graph 1 Methodology of the section. (Source: authors' own graph)

We sort each condition into one out of three bubble sizes, according to their self-care relevance. The influence of lifestyle factors correlates directly with the relevance of self-care to consumers and thus the size of the bubble.

After that, technological feasibility and availability of sensor technology for these conditions are analysed. The obtained products and technical solutions are presented and their underlying technology is explained.

The 3D self-care map merges key findings of the previous sections in a three-dimensional bubble chart. The graphical model is described, major insights are discussed, and implications for distinct groups are given.

2 Theoretical Background

This section gives a description of fundamental terms and approaches which are necessary for the understanding of the work which follows.

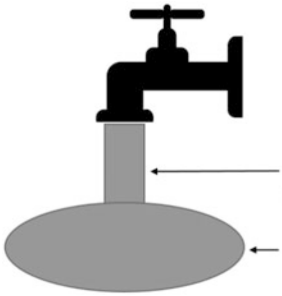
2.1 Medical Perspective

Epidemiology plays an important role in the evaluation of diseases. Last defines epidemiology as "[. . .] the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the prevention and control of health problems." (Porta 1995, p. 55). This definition implies that epidemiology goes beyond pure statistical analysis of diseases by concerning itself with the prevention of health problems.

In the present work, epidemiological methods and key figures are used to determine the *burden of disease* for each of the selected diseases (Graph 2).

This work concentrates on the determination of basic epidemiological key figures for the selected diseases. Since not all diseases are measured with the same method, multiple epidemiological methods and units are applied and diseases are categorised afterwards to assure compatibility of varying diseases despite different

Graph 2 Incidence and prevalence. (Source: authors' own graph)



epidemiological approaches. Unless specified differently, all key figures refer to Germany. The epidemiological key figures of prevalence and incidence are used to determine the burden of disease.

"The *incidence* of a disease is the rate at which new cases occur in a population during a specified period" (BMJ 2016). Incidence thereby measures the probability of occurrence of a disease within a specific time period, for example, 1 year (12-month incidence). Incidence is generally expressed as the number of cases per 10,000 or 100,000 people. Therefore, the most appropriate measure of disease frequency is incidence. A person newly diagnosed with a certain disease is an incidence case, whereas a person suffering from the same disease for a longer period of time is a prevalence case (BMJ 2016).

"The *prevalence* of a disease is the proportion of a population that are cases at a point in time" (BMJ 2016, p. 16). Prevalence represents the total number of individuals who are either suffering from the disease during a period of time (*period prevalence*), or who were suffering from the disease at a particular date (*point prevalence*). Prevalence is generally expressed as a percentage or as the number of cases per 10,000 or 100,000 people (National Institute of Mental Health n.d.). *Lifetime prevalence (LTP)* represents a particular form of period prevalence. It describes the relation between the number of people in the population of study, who at some point in their lives experienced the diseases, and the total population. Certain sources indicate a *total prevalence (TP)* for diseases without more detailed description. Within the scope of this work, it shall be assumed that total prevalence and lifetime prevalence describe the same and will therefore be equated for reasons of simplification.

2.2 *Self-Care Perspective*

The issue of health has gained high importance among OECD countries which is evidenced by the fact that public health expenditure is expected to increase significantly in those countries within the next 15 years (OECD 2015). In this context, the term *health literacy* was firstly discussed on a broad level in the

Anglo-Saxon area over the last 15 years but has received and continues to receive rising attention in Germany in the meantime. Depending on the context and focus, differing interpretations are associated with the term which makes a generally accepted definition difficult.

The US Department of Health and Human Services provides a widely used definition of the term by defining *health literacy* as "[. . .] the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (U.S. Department of Health and Human Services 2000).

In this context, health literacy concerns the ability of individuals to not only obtain and process health information but also understand them in order to make proportionate decisions for themselves (Wagner and Sparr 2012). The concepts of health literacy and self-care are closely linked to each other. Health literacy is a prerequisite for *self-care*, which was defined by WHO as "[. . .] the ability of individuals [. . .] to promote health, prevent disease, and maintain health and to cope with illness and disability with or without the support of a health-care provider" (World Health Organization 2009, p. 17).

On that score, *individual self-care* emphasises individuals and aims to prevent and inhibit diseases, preserve health and cope with diseases on an individual level. This means that decision-making competency and action competency is shifting away from traditional healthcare providers such as hospitals and doctors and towards individuals (Graph 3).

This development is very clearly seen in the field of lifestyle-related diseases. *Lifestyle-related diseases* or short *lifestyle diseases* besides social, economic, and environmental determinants refer to the occurrence of diseases which are primarily based on the habitual behaviour of individuals, including bad eating habits, incorrect posture and a lack of physical activity (Egger and Dixon 2014; Sharma and Majumdar 2009).

Consequently, the individual is at least partially responsible for their own health and the manifestation of lifestyle-related diseases. Derived from individual self-care, the term *consumer self-care* is introduced within this work to highlight the relationship between consumer habits, lifestyle and lifestyle-related diseases. In reverse, it means that a change in behaviour in the wake of an increase in health literacy and individual self-care may prevent lifestyle-related diseases and leads to a decline in those diseases (Willett et al. 2006).

It is necessary for consumers to know and understand the aetiology of these diseases. The word *aetiology* is a medical term and means the cause of a medical condition (Merriam-Webster n.d.-a). The analysis of aetiologies of diseases helps to assess which medical conditions are not, partially or mainly lifestyle-related.

Graph 3 Used self-care terms. (Source: authors' own graph)

For the purpose of this section, the term *self-care relevance* describes the extent to which a certain medical condition is influenced by lifestyle-related causes and factors and the influence consumers have on this condition.

2.3 Technological Perspective

In order to empower consumers to monitor their medical condition without the help of healthcare professionals, it is necessary to provide precise, accessible and easy-to-operate technologies to enhance individual self-care. The Merriam-Webster dictionary defines *technology* as “a capability given by the practical application of knowledge” (Merriam-Webster 2016). These technologies need to be precise enough to recognise and monitor the predetermined medical conditions. To make operation easier and more convenient for consumers without medical knowledge or experience, only *non-invasive* and *minimally invasive technologies* will be presented and evaluated in this work. Non-invasive procedures and devices “[. . .] do not involve tools that break the skin or physically enter the body” (Vorvick 2015b). This includes, among other technologies, trackers, scanners and imaging techniques. Invasive procedures on the other hand enter the body with needles, scopes or other devices (Vorvick 2015a). Minimally invasive technologies require only small incisions or puncturing of the upper skin layers. Hence, those procedures empower a wide range of consumers to take advantage of technologies without the risk of injuries. In the context of this work, a technology is accessible to a wide range of consumers when this technology is offered on the market for consumer electronics. *Consumer electronics* comprises electronic products purchased for private needs (Cambridge Business English Dictionary n.d.). This includes software such as apps, or hardware in the form of devices, trackers, chips, fabrics and conductive products.

3 Burden of Disease

The first dimension of the 3D map focuses on medical conditions and the resulting burden of disease. This section gives a brief description of preselected medical conditions with the help of medical literature. These medical conditions consisting of vital signs and diseases are then categorised and the burden of disease is determined for each disease.

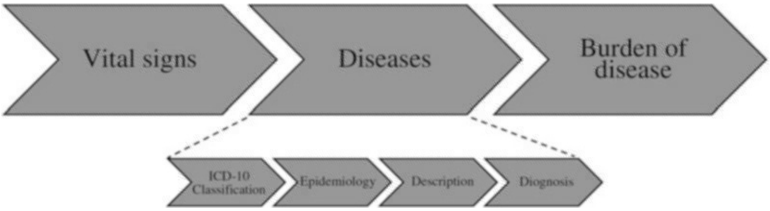
Diseases are substantially aligned with the medical conditions mentioned at Qualcomm’s XPRIZE (XPRIZE Foundation 2012). For a better overview, every medical condition receives an abbreviation which is listed in front of the medical name. Cardiovascular and metabolic diseases are represented by the abbreviation “C”, infectious diseases by “I” and other diseases are represented by the abbreviation “O”.

3.1 Criteria for Medical Conditions

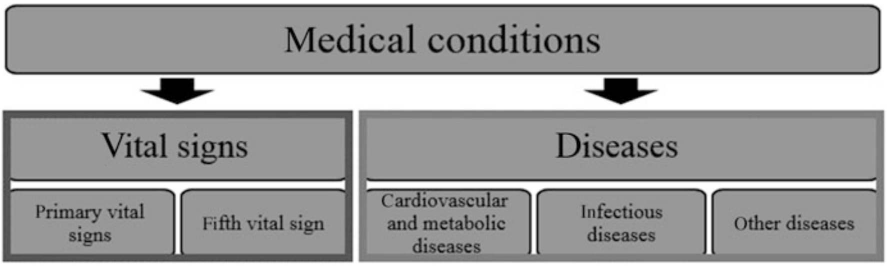
During medical inspections, selected vital signs are measured to get a quick overview of the physical health of a patient. While they are necessary to evaluate health conditions, they are not included in this work, as they do not indicate a condition by themselves. The following diseases are selected as they either predominantly occur in industrialised nations and are expected to spread further, or because they have a strong impact on the affected person. In both cases, non-invasive detection and measurement of these diseases can help consumers to better monitor their medical conditions and help improve their self-care (Graph 4).

A total of 19 diseases are described and analysed in this section. These diseases are grouped into two major categories – cardiovascular/metabolic diseases and infectious diseases. Within this work, metabolic and cardiovascular diseases are merged into one category since they often appear jointly together and affect each other strongly. As malignant melanoma is neither a cardiovascular nor an infectious disease it will be presented below and falls under the category of other diseases (Graph 5).

Every disease is clearly defined and classified by the International Statistical Classification of Diseases and Related Health Problems (ICD-10). The ICD is published by WHO, and its current version ICD-10 is used for this work. It was chosen because this standard is recognised throughout the world and is the most important system for classification and medical diagnosis coding (World Health Organization 2010). For simplification purposes, only the three-digit code without



Graph 4 Medical conditions methodology. (Source: authors' own graph)



Graph 5 Medical conditions composition. (Source: authors' own graph)

subcategories is applied for diseases in this work. If there is more than one disease linked to the three-digit code, only the most common disease will be covered and analysed. Following the classification, the epidemiology will be determined for each disease. This is necessary for the determination of the burden of disease. In order to detect the self-care relevance, it is important to be aware of the ethology, meaning the source of diseases. This is why every disease is shortly introduced and presented. Finally, for the technology selection and the technological feasibility, traditional measurement methods of the presented diseases are discussed.

On the following pages, eight preselected cardiovascular and metabolic diseases, ten infectious diseases and malignant melanoma are described and presented in detail.

3.2 Categorisation of Medical Conditions

3.2.1 Cardiovascular and Metabolic Diseases

According to the Robert Koch Institute, “Cardiovascular diseases are the leading cause of death in Germany, causing a total of approximately 40% of all deaths” (Rober Koch-Institut n.d., p. 1). Reasons for this can be found not only in genetic disposition but in preventable and changeable lifestyle-related factors which are responsible for a growing extent of cardiovascular diseases. An unhealthy diet, alcohol and tobacco consumption and physical inactivity contribute to this development (Rober Koch-Institut n.d.; World Health Organization 2016a; World Heart Federation n.d.). Closely associated with this are also metabolic diseases like diabetes mellitus or high cholesterol which disrupt the normal metabolism of food and negatively affect the metabolic processes of the cells (Enns 2016). Here too, lifestyle-related factors play an important role and increase the risk of acquiring or reinforcing a metabolic disease (American Heart Association 2014; Williamson 2009).

The metabolic syndrome, which is also known as affluenza, should be noticed because it is a widely common disease caused by an unfavourable lifestyle (Wirth et al. 2006). In 2010, prevalence of metabolic syndrome in Germany hit 20% and is expected to continue to rise in the coming years (Chopra et al. 2012; Herold 2010, p. 685). It is known that cardiovascular and metabolic diseases tend to occur and manifest together by building clusters (Huang 2009). Therefore, the metabolic syndrome does not describe a single disease but consists of several risk factors for cardiovascular and metabolic disease. In 2005, the American Heart Association (AHA) in cooperation with the National Heart, Lung, and Blood Institute (NHLBI) delivered an opinion which identifies five risk factors of the metabolic syndrome (Table 1).

The diagnosis of metabolic syndrome is made if at least three out of five of the factors mentioned above are present. This significantly increases the risk of comorbidities or secondary diseases in particular obesity, diabetes mellitus type II,

Table 1 Risk factors for metabolic syndrome

Risk factor	Defining level
Abdominal obesity, given as waist circumference	>102 cm in men (>88 cm in women)
Triglycerides	≥150 mg/dl (Milligram per decilitre)
HDL cholesterol	<40 mg/dl in men (<50 mg/dl in women)
High blood pressure	≥130/≥85 mm Hg (millimetre of mercury)
Fasting glucose or type II diabetes mellitus	≥100 mg/dl

Content: Grundy (2005). (Source: authors' own table)

obstructive sleep apnoea and other cardiovascular/metabolic diseases (Herold 2010, p. 686 f; National Heart, Lung, and Blood Institute 2016).

C1 cholesterol screen (high cholesterol)	ICD-10 classification: E78	Epidemiology: total prevalence, 65% (men), 66% (women) Prevalence, 57% (men cholesterol >190 mg/dl), 61% (women cholesterol >190 mg/dl) (Robert Koch-Institut 2014b)

Cholesterol appears in the form of high-density lipoprotein (HDL), low-density lipoprotein (LDL) and overall cholesterol. High cholesterol level is seen as a metabolic disease, which may harm blood vessels and is responsible for inadequate blood circulation, strokes and heart attacks (American Heart Association 2016b). Besides genetic predispositions and drug-drug interaction, lipid metabolism mainly develops on the basis of an unfavourable lifestyle, in particular, high calorie and sugar intake and excessive alcohol consumption. As a result, lipid metabolic disorder is frequently a comorbidity of diabetes mellitus, obesity and hypertension (Herold 2010, p. 668; Prinz and Ott 2012, p. 39). The most common and reliable method for examination of cholesterol is a blood sample.

C2 diabetes mellitus (type II)	ICD-10 classification: E10–E14	Epidemiology: LTP, 9.3%

Diabetes mellitus is a chronic metabolism disorder, which occurs as a result of reduced or missing insulin production of the pancreas or if the body cannot make effective use of insulin (World Health Organization 2016b). Diabetes substantially increases the risk for comorbidities and secondary diseases like heart attacks and sleep apnoea syndrome (Herold 2010, p. 686 f.; Robert Koch-Institut 2015a). While type I diabetes stems from a genetically predisposed autoimmune disease which presents around 5% of all diabetics, type II diabetes accounts for 95% of all cases and is predominantly lifestyle-related (Piper 2013, p. 466). Reason for type

II diabetes is an acquired autoimmune disease which stems from unhealthy diet, increased calorie intake and inactivity (Williamson 2009). As a result, 80% of type II diabetics develop obesity and other cardiovascular diseases like sleep apnoea syndrome (Herold 2010, p. 682). Glucose control takes place by invasive blood draw (American Diabetes Association 2016).

C3 hypertension	ICD-10 classification: I10	Epidemiology: LTP, 25% (Herold 2010, p. 298)

Hypertension, also known as high blood pressure, designates a steadily increased blood pressure as a result of diseases of the vascular system. High blood pressure cause permanent damages to major organs and may lead to life-threatening diseases like strokes and heart attacks (Deutsche Hochdruckliga e.V. DHL 2015). Hypertension is particularly benefiting from lifestyle-related factors, namely, an unhealthy diet, salt and sugar consumption, disproportionate caffeine intake and alcohol as well as tobacco consumption and stress. Being obese or having diabetes are significant risk factors for getting hypertension (Herold 2010, p. 290; Prinz and Ott 2012, p. 39). Blood pressure monitors and sphygmomanometers are most commonly used for non-invasive blood pressure detection but are less precise than invasive methods.

C4 chronic obstructive pulmonary disease (COPD)	ICD-10 classification: J44	Epidemiology: prevalence 13% (at the age of 40+ and increasing) (Geldmacher et al. 2008)

Chronic obstructive pulmonary disease (COPD) is a highly preventable bronchial obstruction with chronic cough, sputum and bacterial infestation (Herold 2010, p. 333 f.). COPD is the fourth most common cause of death worldwide and the most common respiratory disease. COPD is triggered by cigarette smoke in 60% of all cases (Piper 2013, p. 206; Prinz and Ott 2012, p. 65). Other lifestyle-related risk factors are diabetes mellitus and hypertension (Herold 2010, p. 281). In diagnostics, the lung function is tested with the help of a spirometer or by detecting the airway resistance (Johns et al. 2014).

C5 anaemia (iron deficiency)	ICD-10 classification: D50-D64	Epidemiology: prevalence 10% (in Europe) (Herold 2010, p. 21)

Anaemia describes a reduced concentration of haemoglobin content or erythrocytes under 8.06 mmol/l (13 g/dl) for men and 7.44 mmol/l (12 g/dl) for women in the blood (Herold 2010, p. 23). Low values of haemoglobin limit the oxygen uptake capacity which may result in fatigue, dizziness, shortness of breath up to tachycardia and heart attacks (National Heart, Lung, and Blood Institute 2014). 80% of anaemia are iron-deficiency anaemia caused by a lack of iron in the blood (Herold 2010, p. 21). Invasive blood counts provide insights about haemoglobin concentration, the number of erythrocytes and iron deficiencies (Herold 2010, p. 28).

C6 atrial fibrillation	ICD-10 classification: I48	Epidemiology: prevalence 1% (increasing, 10% at age 75) (Schuchert et al. 2005)

Atrial fibrillation (AF) is characterised by a quivering or irregular heartbeat which may lead to strokes, blood clots and heart-related complications (American Heart Association 2016a). The possible causes for the disease are diverse. Hypertension, alcoholism and thyroid disorders are other reasons which may lead to atrial fibrillation (Piper 2013, p. 106; Schnabel 2012). Atrial fibrillation is detected by long-term electrocardiograph (ECG) (Herold 2010, p. 274).

C7 hypothyroidism/hyperthyroidism	ICD-10 classification: E00-E07	Epidemiology: prevalence (in general medical practice) 6% (iodine deficiency-related), 2% (hypothyroid), 2% (hyperthyroid) (Schulz et al. 2012)

The thyroid plays an important role in the energetic metabolism, influences the formation of hormones and controls cell growth (Cheng et al. 2010; Pascual and Aranda 2013). Most common disorders are thyroid insufficiency (hypothyroidism) and overactive thyroid (hyperthyroidism). Lifestyle-related factors which affect thyroid diseases are tobacco use, alcohol and daily iodine intake (Prinz and Ott 2012, p. 269). Imaging techniques like sonography or laboratory diagnostics help to identify thyroid disorders. Thyroid hormones can be found in serum from patients or with the help of a thyroid-stimulating hormone (TSH) and free T4 (fT4) screening (Piper 2013, p. 537 f.).

C8 sleep apnoea (OSAS)	ICD-10 classification: G47	Epidemiology: prevalence 4% of men/2% of women (middle aged) (Piper 2013, p. 198 f.). LTP 1,9% (OSAS) (Hein 2004).

Sleep apnoea means the temporary interruption of breathing around mouth and nose for more than ten seconds. The complete interruption may last for up to two minutes (Piper 2013, p. 198 f.). In 90% of cases, an obstructive sleep apnoea (OSAS) is diagnosed, which means that parts of the respiratory tract are blocked by the thorax (Herold 2010, p. 325; Piper 2013, p. 199). It is notable that 80% of SAS patients are obese and every second smoker above the age of 40 suffers from obstructive ventilation disorders. Reasons for sleep apnoea are diabetes mellitus, obesity, smoking as well as alcohol and hypertension (Penzel et al. 2005; Piper 2013, p. 199). Diagnostic entails either ambulant screening unit which are able to measure oxygen saturation at night or polysomnography screening in the sleep laboratory (Herold 2010, p. 323).

3.2.2 Infectious Diseases

Worldwide, infectious diseases rank among the most frequent causes of death. In Germany, especially newly arising infectious agents and increasing resistance of bacteria to common antibiotic medicines present challenges (Robert Koch-Institut and Destatis 2015).

The Merriam-Webster Medical Dictionary defines infectious disease as "a disease caused by the entrance into the body of organisms (as bacteria, protozoans, fungi or viruses) which grow and multiply there" (Merriam-Webster n.d.-b, p. 1).

Not every infection necessarily manifest itself in the form of an infectious disease. Consumers' risk of developing an infectious disease depends on the type of infection, its pathogens and the physical condition of the consumer (Bundesministerium für Gesundheit 2016). High hygiene standards and monitoring as well as preventive vaccinations also reduce the risk of acquiring an infection (World Health Organization 2008).

The preselected infectious diseases are being described in the following section.

I1 food-borne illness	ICD-10 classification: A05	Epidemiology: 12-month prevalence, 10% (per year in Germany) (Tschäpe 2000)

After the consumption of contaminated food, a food-borne illness may occur. Typically, food poisoning lasts for 1 or 2 days. Depending on the cause and pathogens, first feelings of unease can be seen after only 1–16 hours after consumption. Besides viral and fungal infections and heavy metals impurities, it is primarily bacteria which cause food-borne illnesses. Medical anamnesis is sufficient to determine whether or not food-borne illness is present. Only laboratory samples can detect specific pathogens (Herold 2010, p. 825 f).

I2 human immunodeficiency virus (HIV)	ICD-10 classification: B20-B24	Epidemiology: in total >83.400 infected people in Germany in 2014 (Koch-Institut 2015). Incidence: 4.5/100,000 (in Germany 2015) (Robert Koch-Institut 2016a)

Human immunodeficiency virus (HIV)-infected patients suffer from a severe loss of CD4-T lymphocytes which are an important part of the immune system (Piper 2013, p. 770). This causes loss of the normal immune system function in the long term. This process is irreversible and entails other bacterial and viral infections such as herpes zoster, because of the weakening immune system. HIV is transmitted via blood, sperm, vaginal secretion and breast milk. HIV is mainly spread by unprotected sex. In 8% of the cases, HIV is transmitted by contaminated needles (needle exchange) between drug users (Herold 2010, p. 853). Positive detection of an HIV infection is detected within 6–12 weeks after the infection. Serological examination can prove HIV with the help of antigens (Robert Koch-Institut 2016b).

I3 infectious mononucleosis	ICD-10 classification: B27	Epidemiology: prevalence of EBV 95% (up to age 30 in Western Europe) (Herold 2010, p. 816)

Infectious mononucleosis or glandular fever is a widely prevalent infectious disease associated with strong swelling of the lymph nodes, high fever, fatigue and sickness. (Herold 2010, p. 816; Piper 2013, p. 849). Infectious Mononucleosis is triggered by the Epstein-Barr-virus (EBV), which belongs to the herpes virus family. At the age of 30, 95% of the population is infected with EBV. Even after full recovery, the virus stays in the body. The analysis of a blood sample detects activated T-lymphocytes and identify the virus. Antibody demonstration is performed with the Paul-Bunnel test (Herold 2010, p. 817; Piper 2013, p. 850).

I4 leucocytosis	ICD-10 classification: D72	Epidemiology: incidence 8% (estimated) (Denzlinger 2014; Herold 2010).

In case of excessive increase of white blood cells, which means more than 4×10^9/l to 11×10^9/l, then one talks of a leucocytosis. Aetiologies are manifold, especially for neutrophilia. Bacterial infections, resulting from inflammation and anti-inflammatory drugs are the most frequent reasons. Metabolic disorders such as diabetes mellitus and lifestyle-related factors, namely smoking, stress and physical strain are further reasons of neutrophilia (Herold 2010, p. 56). Blood count gives information about the amount of white blood cells and granulocytes.

I5 otitis media	ICD-10 classification: H65–H67	Epidemiology: cumulative prevalence 61.4% (children, within the first 6 years) LTP up to 2.6% (in Great Britain) (Browning and Gatehouse 1992).

Otitis media means a painful inflammation of the mucous membranes of the middle ear, commonly triggered by bacterial or viral infection of the respiratory passages (Thacker et al. 2006). The peak of cases occurs in early childhood, making it difficult to gain reliable epidemiological figures in adulthood (Deutsche Gesellschaft für Hals-Nasen-Ohrenheilkunde und Kopf und Hals-Chirurgie e.V. 2014). Otitis media is caused by viral or bacterial infections (pneumococci, haemophilus influenza) (Herold 2010, p. 361 ff.; Prinz and Ott 2012, p. 382). Key component of diagnosis is the physical microscopic examination of the ear by an otologist. In case of a positive result, a sputum analysis test can identify potential pathogens (Thomas et al. 2014).

I6 pertussis (whooping cough)	ICD-10 classification: A37	Epidemiology: incidence 42/100,000 (in eastern Germany in 2011–2012) LTP: 1.9% (infants from 0 to 2 years in 2009–2012) (Neuhauser and Poethko-Müller 2014)

Pertussis, colloquially called “whopping cough”, is a severe or even deadly infectious disease which invades the airways (Herold 2010, p. 836). Pertussis is transmitted via droplet infection and is triggered by the bacterium *Bordetella pertussis* which settles at the respiratory tract (Robert Koch-Institut 2014a). Vaccinations at periodic intervals lower the risk of contracting pertussis significantly. Diagnosis of a pertussis infection is dependent on the stadium of the disease. At an early stage, bacterial pathogens are detected from nose swab or secretion. After 2 weeks, proof of antigens can be found in the serum after the use of an enzyme-linked immunosorbent assay (ELISA) (Riffelmann et al. 2008).

I7 pharyngitis (chronic)	ICD-10 classification: J02	Epidemiology: incidence 30% (within 12 months) (Wächtler and Chenot 2011)

Pharyngitis also referred to as strep throat means a throat infection accompanied by sore throat, fever and shivering. It is one of the most common diseases; 20% of people seeing a doctor show symptoms of a pharyngitis (Fink and Haidinger 2007). In 50–80%, viruses cause pharyngitis (Wächtler and Chenot 2011). The most frequent bacterial pathogen is *Streptococcus pyogenes* (Robert Koch-Institut 2009). Usually, endoscopic examination of the throat is sufficient for detection of a pharyngitis infection. Rapid antigen detection tests can be used for the detection of streptococcus (Robert Koch-Institut 2009).

I8 pneumonia	ICD-10 classification: J12–J18	Epidemiology: LTP 20% (in Germany) (Prinz and Ott 2012, p. 66)

Pneumonia is referred to as an inflammatory, infectious disease of the lung tissue often associated with cough, fever, sputum and chest trouble, which can cause death, if left untreated (Prinz and Ott 2012, p. 66). Pneumonia is the third leading cause of death worldwide (Herold 2010, p. 356). In 90% of all causes, a CAP is caused by a bacterial infection, namely, pneumococci, staphylococci or *Streptococcus pneumoniae*. Lifestyle-related risk factors, which contribute to pneumonia, are other lung diseases such as COPD, diabetes mellitus, alcoholism and a weakened immune system resulting from an HIV infection (Jacobi et al. 2009). Anamnesis and auscultation are first steps for the detection of pneumonia. In case of a suspected infection, radiographs and in some cases, a computer tomography is laid down. The exact pathogens can be identified in the blood or sputum (Piper 2013, p. 225 f).

I9 herpes zoster (shingles)	ICD-10 classification: B02	Epidemiology: >95% of adults show antibodies against VZV (Herold 2010, p. 812) Prevalence 50% (for shingles in adults at the age of 85) (Robert Koch-Institut 2016c)

Varicella zoster virus (VZV) causes two different clinical pictures: varicella (chickenpox) and herpes zoster (shingles). Primary infection which leads to varicella appears mostly during childhood. The virus stays inside the body and can be reactivated, which then leads to shingles (Piper 2013, p. 846; Robert Koch-Institut 2016c). Risk factors include melanoma, intense sun exposure and stress, which additionally weaken the immune system (Herold 2010, p. 812; Prinz and Ott 2012, p. 411). Diagnosis is based on anamnesis and visual diagnosis. In rare cases, the virus is detected via polymerase chain reaction (PCR) test.

I10 urinary tract infection	ICD-10 classification: N39	Epidemiology: LTP >50% (for women in Germany) (Hummers-pradier and Schiemann n.d.; Wagenlehner 2015) LTP 12% (adult males in the USA) (Brumbaugh and Mobley 2012)

Infectious pathogens of the urinary tract may lead to an urinary tract infection (Herold 2010, p. 592). In 80% of all cases, the bacterium *Escherichia coli* (*E. coli*) is responsible for the infection. Besides anatomic reasons, like an obstructive urinary flow disorder, immune deficiency, sexual activity and metabolic diseases favour infections of the urinary tract. Due to high blood and urine glucose levels, people with diabetes are at a higher risk of developing urinary tract infections (Saliba et al. 2015). Evidence of an infection is provided by urine samples, which prove leucocyturia and infectious bacteria.

3.2.3 Other Diseases

Malignant melanoma is neither a cardiovascular/metabolic disease nor an infectious disease and therefore listed separately as other disease.

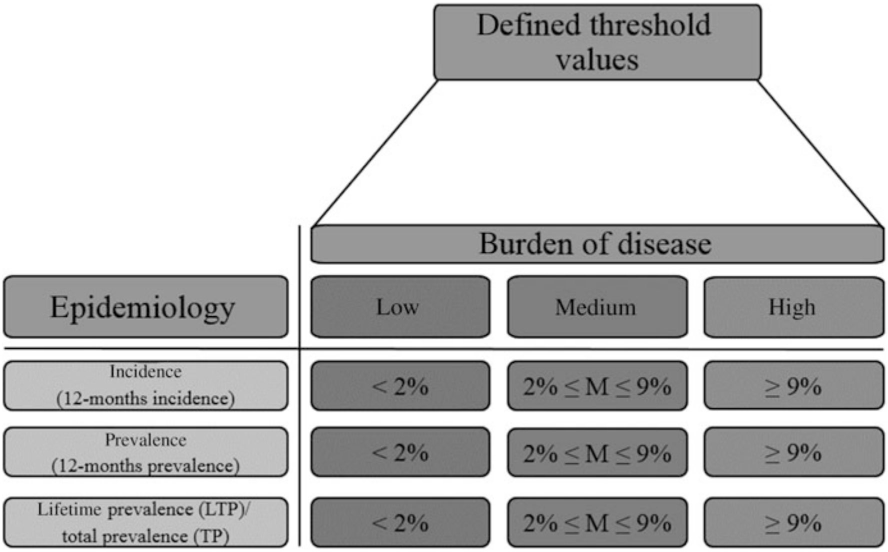
O1 malignant melanoma	ICD-10 classification: C43	Epidemiology: LTP 1%, incidence 15/100,000 (DKG, Deutsche Krebshilfe, and AWMF 2014; Sondak and Smalley 2009)

Malignant melanoma is a malignant tumour of melanocytes, the pigment cells of the skin and the most malignant form of skin cancer. This tumour type grows rapidly and disseminates metastases via blood and lymphatic pathways from an early stage. Disease rates in Germany have steadily increased over the last decades (Kraywinkel et al. 2012). People with light skin and a high number of pigments are at particular risk. A lifestyle-related factor, which is responsible for malignant melanoma, is UV exposure (Zentrum für Krebsregisterdaten 2013). Malignant melanoma is generally detected by visual diagnosis or microscopic examination of a dermatologist.

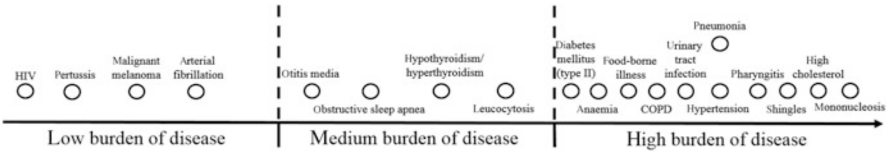
Based on the epidemiological information of each disease given in the former section, the burden of disease is determined and each condition is then sorted into one of three categories, according to their prevalence and incidence rates.

For this work, the burden of disease indicates one person's probability for developing a disease within a certain period of time or of having a disease at a specific point in time. With the concept of prevalence and incidence described in Sect. 2, the burden of disease is determined. It should not be confused with the Global Burden of Disease, which evaluates mortality and disability caused by major diseases and injuries and which is used by several organisations, such as the WHO or Harvard School of Public Health since 1990 (World Health Organization n.d.). Due to difficult data collection and non-comprehensive basis of data for the determination of disability-adjusted life years (DALY), the concept of Global Burden of Disease was dispensed for this work (World Health Organization 2016d).

In order to be able to determine the corresponding burden of disease for each condition, three categories are being used. Each category is defined by its epidemiological thresholds for incidence, prevalence and lifetime prevalence/total



Graph 6 Threshold values of the burden of disease. (Source: authors' own graph)



Graph 7 Burden of disease map. (Source: authors' own graph)

prevalence. With this, each disease can be sorted into one category based on their incidence or prevalence rate, resulting in a low, medium and high burden of disease.

Thresholds and categories for individual epidemiological key figures are valued as follows (Graphs 6 and 7).

After categorising all diseases on the basis of their epidemiology and applying the criteria which were mentioned above, the burden of disease for each condition is presented in the graph:

On the X-axis, diseases are sorted according to their burden of disease in ascending order. On the left, there are diseases with a low burden of disease, while on the right, there are conditions which were categorised as conditions with a high burden of disease.

The low and medium burden of disease categories are each represented by four diseases. It must be observed that while the burden of disease might be low for some conditions, correct and prompt treatment for these diseases (HIV, pertussis, malignant melanoma) still is essential and a lack of treatment may even lead to death (AIDS.gov 2015; Sandru et al. 2014). Mortality and morbidity are not related to the burden of disease.

It turns out that more than half of the examined diseases, 11 out of 19% or 57.9%, show a high burden of disease. This includes both cardiovascular/metabolic diseases and infectious diseases, which tend to have high prevalence and incidence rates. This especially includes diabetes mellitus, hypertension and high cholesterol which are all components of metabolic syndrome. In addition, diabetes and hypertension are also main risk factors of COPD, which once again favours chronic pharyngitis. This confirms the statement claiming that cardiovascular and metabolic diseases often occur and manifest together and tend to be accompanying illnesses or secondary diseases of each other.

In a nutshell, more than half of the conditions show a high burden of disease. This applies in particular for cardiovascular/metabolic diseases which tend to be closely interrelated, whereas this is less applicable for infections with a high burden of disease.

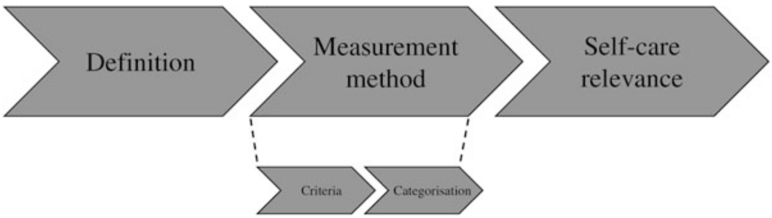
After having categorised and determined the burden of disease for each condition, the impact of lifestyle-related causes and risk factors for the development of diseases is examined in the next section.

4 Self-Care Relevance

This section focuses on lifestyle-related causes and risks and their impact on diseases from the previous section.

With the help of medical literature and scientific studies, potential causes and risk factors of diseases are listed, and each condition is categorised in relationship to its lifestyle-related causes and risk factors. Finally, the self-care relevance for each disease is determined and graphically illustrated (Graph 8).

Self-care relevance describes the extent to which a certain medical condition is influenced by lifestyle-related causes and factors and the influence consumers have on this condition. Accordingly, a low self-care relevance indicates that a disease is not or only to a small extent induced by lifestyle and lifestyle-related factor of individual consumers. On the other hand, a high self-care relevance implies that a disease is highly or predominantly induced or even caused by lifestyle and lifestyle-related factors of individual consumers. The term has been chosen to point out which



Graph 8 Self-care relevance methodology. (Source: authors' own graph)

diseases are impacted by consumers. In other words, diseases with a high self-care relevance can be positively influenced by lifestyle changes made by consumers themselves without the need of medical institutions, while diseases with a lower self-care relevance may be the result of other non-lifestyle-related causes.

The aim of self-care relevance is twofold. On the one hand, the impact of lifestyle-related factors on diseases is examined. On the other hand, it is outlined which disease condition may improve or even heal due to lifestyle changes of the consumer. Two assumptions are made:

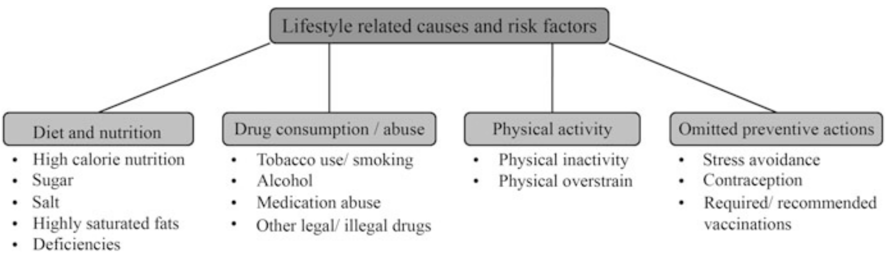
1. Consumers are in a position to make conscious changes in lifestyle.
2. High and medium self-care-relevant diseases are positively affected by specific changes of lifestyle.

If both assumptions apply, it can be said that the higher diseases are impacted by lifestyle-related factors, the higher is their self-care relevance and the more consumers can influence the progress of diseases on an individual level by making lifestyle changes.

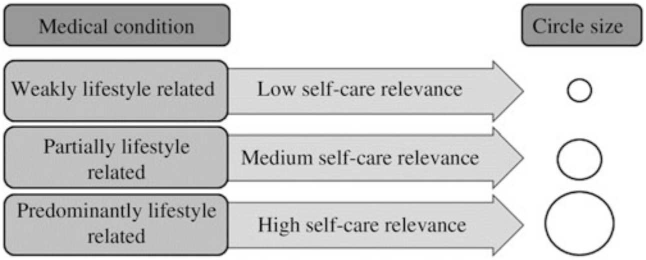
4.1 Criteria for Self-Care Relevance

Self-care relevance for each disease is determined by evaluation of medical literature and studies. Based on the description of diseases in Sect. 3, additional literature is used to detect known causes and risk factors. A distinction is made between lifestyle-related and non-lifestyle-related causes and risk factors in order to determine the self-care relevance later on. Due to reasons of complexity, correlations and interdependencies of causes and risk factors are not taken into account, but causes and risk factors are listed in the same category.

Whereas the gaining of insights is the main purpose in this work, the level of details regarding methodical approaches and medical context has to be narrowed at some point. For this work, lifestyle-related causes and risk factors are subdivided into four areas which are defined as follows (Graph 9).



Graph 9 Lifestyle-related causes and risk factors. (Source: authors' own graph)



Graph 10 Self-care relevance circle size mapping. (Source: authors' own graph)

Other factors which are not listed above are counted as non-invasive lifestyle-related causes and risk factors. In addition, it is recalled that occupational risks (increased risk of infections for doctors and staff working for healthcare institutions, sun exposure of construction workers) are not considered as lifestyle-related causes and risk factors. Also excluded are actions and risks which are not self-inflicted (accidents, passive smoking, childhood vaccination). All causes and risk factors apply to Germany unless otherwise noted.

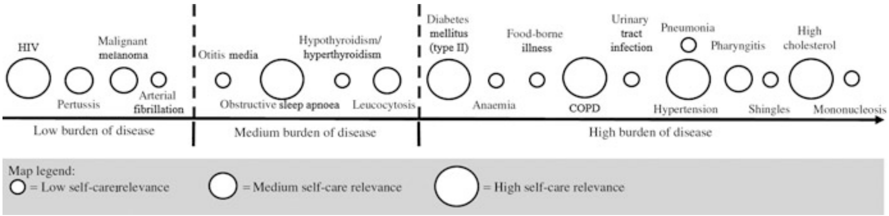
As an analogy to Sect. 3 diseases are continued to be classified in cardiovascular/metabolic, infectious and other diseases.

Thereafter, every category is assigned to a degree of self-care relevance. Diseases which have been detected as being weakly lifestyle-related diseases receive a low self-care relevance. Diseases which have been detected as partially lifestyle-related diseases are marked with a medium self-care relevance, while diseases which have been detected as predominantly lifestyle-related diseases receive a high self-care relevance. Moreover, the circle size of each disease represents the self-care relevance of each condition (Graph 10).

4.2 Categorisation of Self-Care Relevance

All diseases described in Sect. 3 are sorted into one of the three categorises on the basis of their lifestyle-related causes and risk factors which are described above.

Thus, three infectious diseases and malignant melanoma are considered as partially lifestyle-related diseases. Thereby, nine out of ten infectious diseases are only weakly or partially lifestyle-related and can be tracked back to other causes and risk factors such as heredity, pathogenic microorganisms and pathogenic molecules. Five cardiovascular/metabolic diseases and one infectious disease are considered as predominantly lifestyle-related diseases. Remarkable is the fact that five out of six predominantly lifestyle-related diseases are cardiovascular/metabolic diseases. Moreover, diabetes mellitus, hypertension, high cholesterol, COPD and OSAS share mainly the same causes and risk factors: This includes in particular an unfavourable diet (high in calories and sugar-rich nutrition), which often results in obesity, alcohol



Graph 11 Self-care relevance map. (Source: authors' own graph)

and tobacco use and physical inactivity. In conclusion, it must be said that especially diabetes mellitus, hypertension and high cholesterol are closely linked with each other, and these diseases are frequently accompanying, co-existing, or are secondary diseases.

The goal of the self-care relevance map is to visualise all diseases and to set them in relation to their lifestyle-related causes and risk factors in order to determine which diseases can be influenced by consumers. The self-care relevance for each disease is symbolised by the circle size of the condition. Furthermore, conditions are sorted into ascending order starting with a low burden of disease and growing rightwards (Graph 11).

The evaluation of results shows that non-lifestyle-related causes and risk factors for cardiovascular diseases are mainly advancing age and familial dispositions (heredity). It is also apparent that the main causes and risk factors for cardiovascular diseases are high caloric, poor diets with highly saturated fat and sugar intake; drug consumption, mainly represented by alcohol and tobacco use; as well as physical inactivity.

Regardless of the burden of diseases, the large majority of cardiovascular and metabolic diseases fall into the high self-care category (5/8 cardiovascular/metabolic diseases). Five out of six diseases which are located in the high self-care category are cardiovascular and metabolic diseases. Diabetes mellitus, hypertension, high cholesterol and COPD are predominantly lifestyle-related, and both show a high burden of disease and a high self-care relevance.

For this reason, the focus lies on those four cardiovascular and metabolic diseases and less on infectious diseases since these conditions are mainly caused by pathogenic microorganisms and pathogenic molecules and are less affected by lifestyle changes. Also the focus is on the measurement and monitoring of vital signs, which in many cases are necessary and suitable for the detection of diseases like high cholesterol or diabetes mellitus.

5 Technological Feasibility

This section focuses on technologies for detection and measurement of the medical conditions mentioned in Sect. 3. To achieve this, available and suitable technologies are identified through systematic search, evaluated and categorised in accordance with their technological feasibility (Graph 12).

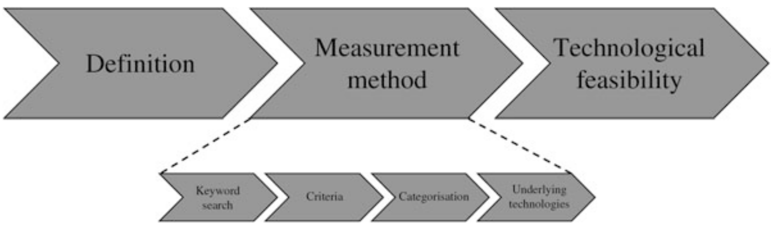
For his work, “technology” refers to both software and hardware which are capable of detecting and measuring medical conditions in consumers. For the purpose of simplification, throughout this work, technology covers all approaches, concepts, prototypes, products, sensors and devices dealing with non-invasive technologies for the measurement of medical conditions. In addition, detected technologies need to be as precise as possible, easy to use and accessible for consumers in order to enhance individual self-care.

Sufficiently precise means that a technology is able to reliably identify and measure individual or multiple medical conditions. This can be ensured through governmental and independent institutions which certify devices. In particular, this includes the CE marking for medical devices within the European Union, ISO standards, and FDA-cleared or FDA-approved devices. In order to receive one of these certificates, devices must not only pass a harmlessness test but also need to fulfil capability tests, environmental compatibility and meet additional quality requirements.

Ease of use of a technology is ensured, when consumers are able to handle the technology without the help of medical staff or deeper technical understanding. To this end, only non-invasive and minimally invasive technologies are examined. Such technologies minimise the risk of injuries and are easier to handle than invasive methods.

“Availability” relates to whether or not the technology is accessible for the public and if it can be bought and used by consumers. This shall be the case if the technology is available and sold as consumer electronics. In Section 2.3 above consumer electronics were defined as electronic products purchased for private needs. Accordingly, these technologies are directed at private consumers.

The more these three criteria are fulfilled, the more advanced the technology is considered to be. Categorising these technologies serves as a qualitative assessment of the technology without evaluating technical details. The section derives the



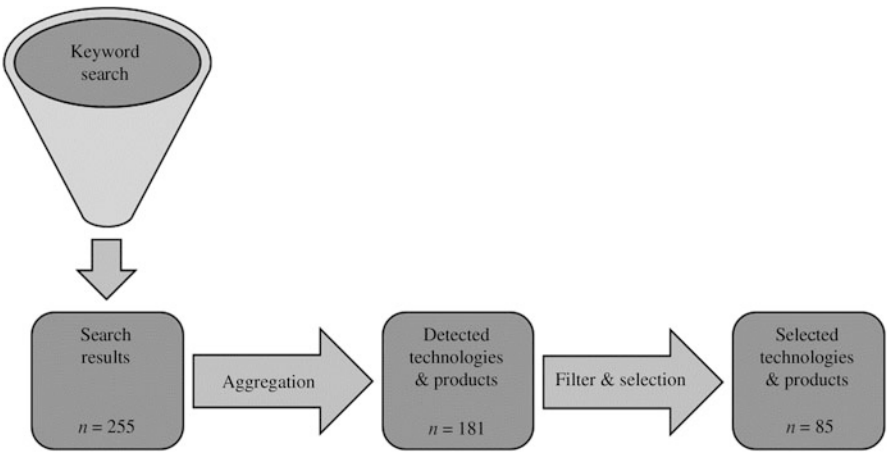
Graph 12 Technology methodology. (Source: authors’ own graph)

technological feasibility for each medical condition from the categorisation of technologies. The technological feasibility indicates how well a medical condition can be measured by private consumers with the use of non-invasive technologies. It is important to note that the technological feasibility does not directly evaluate specific technologies but indicates how advanced the measurement of a medical condition is.

5.1 Criteria for Categorisation

The process of searching, identifying suitable technologies and determining of the technological feasibility of said technologies has four steps:

At first, search keywords help to search for technologies for respective medical conditions. In the second step, the results are aggregated and structured by sorting out duplicate reports, failed and outdated technology concepts and unproven claims of online sources. Following this, the detected technologies and products are filtered. Products which were available on the market before 2005 or which use invasive measurement methods are sorted out. If there is more than one product using the same technology, some manufacturers are selected representatively. The third step involves the explanation of the underlying principles and technologies of the products and devices being studied. Finally, the technological feasibility of each medical condition is determined. Section 5.2 graphically illustrates the technological feasibility of each medical condition and presents major findings (Graph 13).



Graph 13 Keyword search and selection process. (Source: authors' own graph)

Overall, 255 websites, conferences, societies, medical and technology blogs, online journals and commercial sites were screened using the following keywords in combination with medical condition:

Keywords: non-invasive, minimally invasive, consumer electronics, prototype, detection, diagnostic, measurement, monitoring, analysis, innovation, health device, technology, wearable, wearable technology, medical wearable, sensor, tracker, wristband, lenses, tech-tat, medical patch, biotech-tattoo

After aggregating and summarising 181 technology approaches, prototypes, scientific studies, products, sensors and devices were detected; 85 of them were selected after filtering. It has to be taken into account that different medical conditions can be measured by the same technology, implying that the number of technologies is less than the number of selected products.

5.2 Categorisation of Technologies

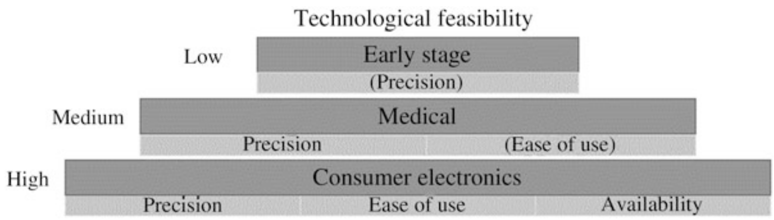
The technological feasibility is divided into the three categories: early stage, medical devices and consumer electronics. The classification is based on the criteria precision, ease of use and availability.

In the category early stage are medical conditions which either cannot be measured with non-invasive technologies or for which only prototypes are available. These technologies are characterised by the fact that they are not user-friendly (lack of ease of use) and are not available on the consumer electronics market (lack of availability). The early-stage category equates to a low technological feasibility.

In the medical device category, there are technologies for the precise, non-invasive measurement of medical conditions which are used in medical facilities (precision). Technologies in this section often need to be operated by professionals (lack of ease of use) and are not available as consumer electronics (lack of availability). The medical device category represents a medium technological feasibility (Graph 14).

Technologies for medical conditions in the consumer electronics category fulfil all three criteria. These technologies are proven to be precise in measurement (precision), simple to use by private consumers (ease of use) and available for private purposes (availability). Medical conditions in this category are valued with a high level of technological feasibility.

The full review of all examined technologies exceeds the scope of this chapter. Nevertheless, some of the examined technologies are presented as finalists for the XPRIZE challenge and are good examples for state-of-the-art technology. Each technology team works towards an own medical tricorder for detection and mea-



Graph 14 Technological feasibility mapping. (Source: authors' own graph)

surement of the presented medical conditions ("Where No Healthcare Device Has Gone Before" 2015). To give an overview of the types of examined technology, the seven finalists are shown below as examples for innovative healthcare technology:

Intelesense-Scanadu: Intelesens, a medical technology company which specialises in intelligent wireless vital signs monitoring, and Scanadu Inc., a Silicon Valley-based medtech company, collaborate to win the XPRIZE challenge. The ultimate goal is to design a tricorder device for vital sign monitoring which is capable of changing the healthcare industry by putting medical devices back into the hands of individuals.

Aezon: After the XPRIZE challenge had been announced, Aezon was founded in September 2012. The team includes students from Johns Hopkins University in Baltimore, USA, and partner with Symcat, which recently developed a symptom checker for diseases. Other partners include SpiroSmart, Aegle, which provide big data analytics for healthcare and the developers of Biomeme, a smartphone-based DNA detection platform.

Danvantri: The team named Danvantri consists of seven professionals and is led by Sridharan Mani, an Indian entrepreneur and IT project manager. They are dedicated to developing affordable but high-quality healthcare solutions based on mobile technologies. The main focus lies on the prevention of diseases by early detection made possible with an all-in-one handheld device.

DMI: DMI comprises experienced scientists, engineers and designers in the area of Boston/Cambridge, USA, and has won the Nokia Sensing XCHALLENGE with their rHEALTH sensor technology. This device also received funding from NASA, the Gates Foundation and National Institutes of Health (NIH). A single drop of blood is taken by the new rHEALTH X1 prototype, which applies it to nanoscale test strips, analyses the sample and links it with possible diagnoses.

Dynamical Biomarkers Group (DBG): DBG is a research group of the Center for Dynamical Biomarkers and Translational Medicine (CDBTM) in Taiwan which includes clinicians, medical researches, scientists and engineers. The main objective is to design light-weight and portable diagnostic instruments with a high diagnostic accuracy and which offer a good user experience and a flexible exchange between medical data and the cloud.

Final Frontier Medical Devices: The team was formed by the brothers Basil and George Harris who founded Basil Leaf Technologies. For the XPRIZE challenge, the company is currently developing a portable consumer-level device called DxtER. This device collects and interprets data to diagnose selected medical conditions in real time and recommend appropriate actions.

Cloud DX: Dr. Sandeep Kohli, a physician and assistant clinical professor of medicine at McMaster University, Canada, founded and leads the Canadian XPRIZE team Cloud DX. The company is working towards a medical device which enables ordinary people to monitor their health status, diagnose selected diseases and get a sense of when they should seek professional medical treatment.

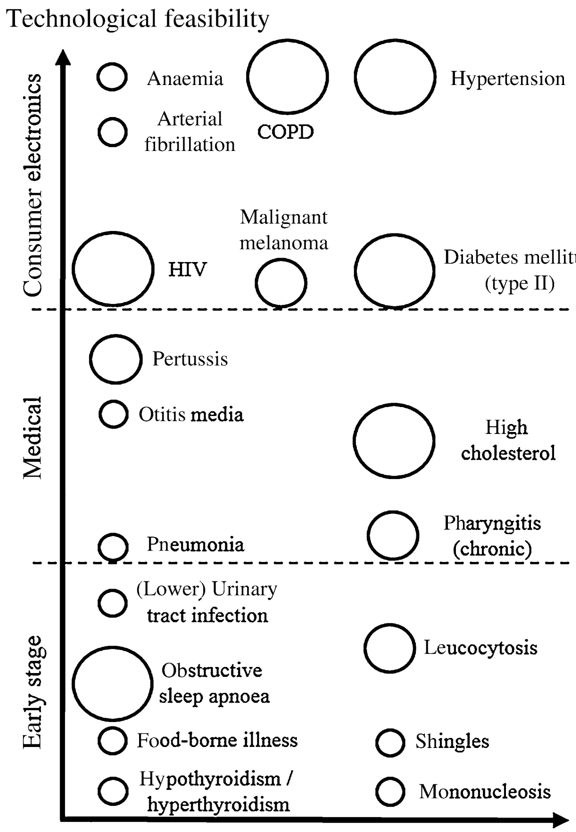
In summary, in the technology section of this chapter, promising concepts, devices and products were presented, underlying technologies were explained, and their technological feasibility was detected based on defined criteria; 85 technologies in the development state of prototypes, medical devices and consumer technology have been reviewed. Following an in-depth investigation and categorisation of technologies, diseases have been sorted into the technological feasibility map and presented graphically. The resulting findings will be explained shortly.

The graph shows each of the examined diseases by their technological feasibility. The vertical y-axis represents the technological feasibility for each disease and is divided into the three sectors: early stage, medical and consumer electronics. Each disease is categorised according to its technological feasibility in ascending order. The higher a disease is listed, the higher its level of technological feasibility. The graph only shows diseases and no vital signs (Graph 15).

It should be noted that medical conditions which are ranked in the same category may show minor differences in their technological feasibility due to the current development status of a technology. A technology, for example, which has undergone only basic tests is less advanced than a technology, which applied for FDA approval.

After assessing the study of the graphical technological feasibility, the following findings should be mentioned:

An even distribution of the examined technologies for each disease onto the early-stage sector (7 diseases), the medical sector (5 diseases) and the consumer electronics sector (7 diseases) can be seen. For almost any medical condition (including vital signs), at least early-stage approaches or research is conducted. However, there are big differences between detection and monitoring of vital signs, cardiovascular/metabolic diseases and infectious diseases. Devices for the measurement of vital signs are not only the most advanced and all located in the consumer electronics sector but are often able to monitor multiple vital signs simultaneously. In some cases, those technologies are also able to detect other medical conditions, such as atrial fibrillation. The majority (5/8) of the technologies for cardiovascular/metabolic disease detection and measurement have reached the consumer electronics sector. Early-stage technologies are almost exclusively occupied by infectious diseases. Apart from HIV detection, no other technology for infectious disease measurement is located in the consumer electronics sector. Reasons for this might be that infections are more difficult to

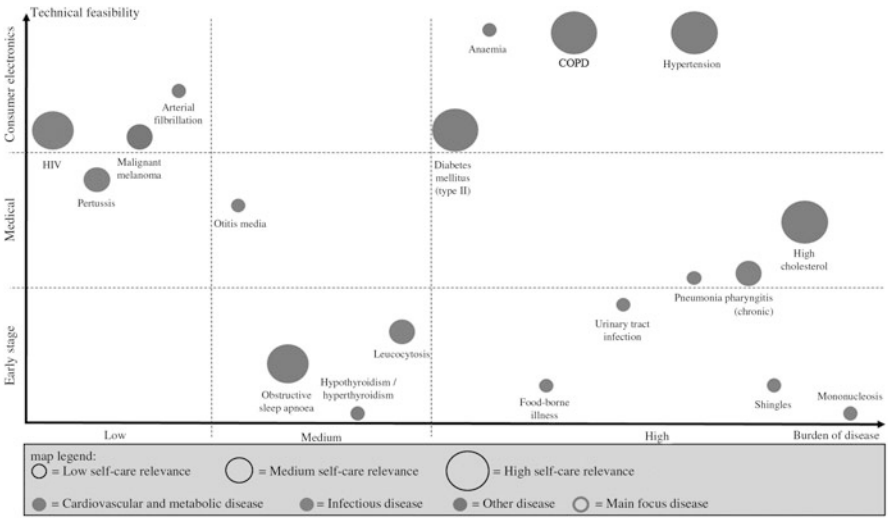


Graph 15 Technological feasibility map. (Source: authors' own graph)

detect than cardiovascular/metabolic diseases due to lack of precision resulting from low sensitivity or specificity and possible impurities of samples.

Furthermore, it can be observed that the examined consumer electronics technologies are more often cleared or approved by the FDA, than technologies in their early stages. As expected, technologies for consumer electronics are usually more precise and better meet medical compliance than early-stage technologies. This is most likely traceable back to a higher degree of feasibility compared to technologies in the early-stage sector.

As a final point, it should be mentioned that some of the devices which are ranked as a consumer electronics device still might need known medical procedures or medical staff for evaluations. For example, the app for malignant melanoma detection or a professional second HIV test after a false positive result. The same applies to minimally invasive measurement methods like the FreeStyle Libre device which still needs a small needle in order to deliver results which are precise enough.



Graph 16 3D self-care map. (Source: authors' own graph)

5.2.1 3D Self-Care Map

Bringing together burden of disease, self-care relevance and technological feasibility, this section graphically presents the main results of previous sections, discusses them and derives practical recommendations for different groups. The 3D self-care map combines the burden of disease, self-care relevance and technological feasibility of each disease within a single graph (Graph 16).

The X-axis of the 3D self-care map is divided into three areas: low, medium and high, and shows the burden of disease ascending, from the left to the right. The burden of disease measures one person's probability for developing a disease within a certain period of time, or of having a disease at a specific point in time (see Sect. 3). The positioning of the disease on the X-axis correlated with the level of burden of disease. The rightmost position on the X-axis indicated the highest level of burden of disease.

The Y-axis indicates the technological feasibility, rising from bottom to top and is categorised into the three sectors: early stage, medical and consumer electronics. The technological feasibility indicates how well a medical condition can be measured by private consumers, through non-invasive technologies (see Sect. 5). The higher a disease is located on the Y-axis, the higher its technological feasibility.

Each disease is represented by a circle. The circle size provides insights into the self-care relevance of a disease. Self-care relevance describes the extent to which a certain medical condition is influenced by lifestyle-related causes and factors and the influence consumers have on this condition (see Sect. 4). The bigger the circle, the higher the self-care relevance of a certain disease. On the basis of this description, several statements can be made.

A high burden of disease was detected by 11 out of 19 diseases, equally distributed among cardiovascular/metabolic and infectious diseases. Major differences can be seen in terms of self-care relevance. Infectious diseases are hardly associated with lifestyle-related factors, mainly resulting in low self-care relevance (6/10 diseases) and medium self-care relevance (3/10 diseases). Lifestyle-related causes and risk factors of infectious diseases and malignant melanoma are mainly attributed to omitted preventive actions. This includes primarily unprotected intercourse (HIV), irregular vaccinations (pertussis) and intense sun exposure (malignant melanoma).

By contrast, cardiovascular/metabolic diseases are predominantly lifestyle-related (5/8 diseases); 5 out of 6 diseases with a high self-care relevance are cardiovascular/metabolic diseases. Lifestyle-related causes and risk factors of these diseases are diet/nutrition (high calories, sugar, and saturated fats), drug consumption (tobacco and alcohol) and physical inactivity. This applies in particular to comorbidities of the metabolic syndrome such as diabetes type II, hypertension and high cholesterol as well as COPD (Geldmacher et al. 2008).

Technologies for detection and measurement of vital signs are consistently high and are established in the consumer electronics sector. A growing number of specific technologies are able to detect and monitor multiple vital signs and diseases such as atrial fibrillation at once.

The technological feasibility of examined diseases is distributed evenly across the early-stage medical and consumer electronics sector (7/5/7 diseases). Aside from HIV, which has reached the consumer electronics sector, infectious diseases are mainly located in the early-stage sector or at the lower end of the medical sector (7/10 diseases). Cardiovascular/metabolic diseases, on the other hand, are represented mainly in the consumer electronics sector (5/8 diseases) and show a high technological feasibility.

Currently for most of the examined medical conditions, there are early-stage concepts and technologies which aim at the consumer electronics market and are planned for completion within the next 3 years.

Increasing precision in the field of detection and measurement of medical conditions, ease of use for consumers and availability of technologies in consumer electronics steadily raise the technological feasibility. Consequently, based on the made assumptions, increased technological feasibility entails growing self-care in private consumers.

6 Discussion

This chapter has demonstrated that cardiovascular and metabolic diseases tend to occur together and are predominantly the result of lifestyle-related factors. Infectious diseases, however, are far less affected by the same lifestyle-related factors. Furthermore, it was found that current research mainly focuses on the development of technologies for the non-invasive measurement of vital signs and cardiovascular/metabolic diseases. A growing number of these technologies are available in the field of consumer electronics and provide precise, non-invasive measurement and ease of use for private consumers. Some technologies already compare measured values with databases in order to provide diagnosis and recommendations for action. As a result, it is seen that individual self-care of consumers becomes increasingly independent of medical diagnostics and advice. Closely associated with this are consumers who gain growing influence on their personal health and decision-making. It is conceivable that these developments will lead to a decentralisation of the healthcare system and further transformation processes in the long term.

Technology solutions, in particular leveraging from the Internet of Things and incorporating sensors in combination with mobile, appear to offer a potential for more tailored and person-centric solutions to facilitate better and sustained health and wellness management. Perhaps while technology in many respects has led to the lifestyle-related factors that are leading to a more sedentary style and thus contributing to increases in the incidents of various chronic conditions, technology may also hold the answer for assisting in addressing the problem and finding appropriate, efficient and effective solutions such as the medical Tricorder.

6.1 Implications for Research and Practice

On the basis of the results, the following implications for consumers, health insurance funds and technology manufacturers can be seen:

Consumers:

I. Consumers should initially focus on managing existing diseases which are categorised with a high self-care relevance such as diabetes type II, hypertension, high cholesterol and COPD. Since these diseases are closely lifestyle-related, consumers themselves could have a major impact by implementing simple lifestyle changes. The focus should lie on minimising lifestyle-related causes and risk factors by optimising diet and nutrition, discouraging drug consumption and enhancing physical activity.
II. Consumers should then aim to prevent diseases with high and medium self-care relevance. Cardiovascular/metabolic diseases may be prevented by proper diet and nutrition, reduced drug consumption and regular physical activity. Infectious diseases may be prevented by vaccinations (pertussis) or safe sex (HIV). The risk of malignant melanoma can be reduced by the avoidance of long periods of intense sun exposure.

Health Insurance Funds:

I. Health insurance funds should address diseases with a combined high self-care relevance and high burden of disease as those cause avoidable, high costs. Through further development of relevant technologies and promotion of health literacy among customers, expenditures can be reduced.

II. Health insurance funds should then deal with diseases with high and medium self-care relevance, due to high and long follow-up costs (HIV and malignant melanoma). Investing in technologies for the detection of these diseases and the preventive education of their customers could help to prevent diseases.
III. Health insurance funds are advised to deal with diseases with a high burden of disease since significant parts of their customers are affected. Technologies for quick and reliable detection of those diseases do not only save time and costs for expensive laboratory tests (infections), but also enable more efficient early treatments of patients.

Technology Manufacturers:

I. Technology manufacturers should implement a market penetration strategy for diseases which have reached a high technological feasibility because the related technologies are already available for consumers and cause only minor further development expenses.
II. Technology manufacturers are encouraged to invest in technologies which detect and monitor diseases with a high burden of disease. Consumer and medical demand is correspondingly large, and potential competitive and pioneer advantages can thereby be realised with early-stage and medical technologies.

6.2 Further Research

This work mainly focused on the aspect of technological feasibility of non-invasive measurement of medical conditions and how medical diseases can be detected and measured, without the support of a healthcare provider. The assumption was made that an increased feasibility directly resonates with an enhanced understanding of self-care by consumers. However, technological enablement itself is only one part which defines self-care and should be complemented with actions to raise awareness and concrete recommendations for consumers. Measurement alone cannot increase self-care of individuals without further actions or lifestyle changes to promote and maintain health, and prevent disease.

Technology search and selection were based on a literature review with a fixed scheme, keywords and filters. The products and technologies represent only a limited selection of existing technical approaches. This is particularly due to the conflict between offering as many promising concepts as possible and in-depth examinations of technologies.

The early description of the medical conditions and epidemiological terms provided a good overview of reasons for their origin, their rate of disease and conventional detection and measurement. This established the basis for the detection of the burden of disease, self-care relevance and technological feasibility within the next sections. It would have been desirable to further limit the amount of technologies, conduct additional interviews with experts and focus more intensely on promising technologies instead.

The aforementioned issue could have been avoided by narrowing down the pool of diseases beforehand. In return, this would have made in-depth analysis of a smaller number of suitable technologies and identification of potential future key technologies possible.

Non-invasive technologies are not only capable of monitoring medical conditions but will also help to prevent diseases through early detection in the near future. It is to be expected that these technologies will no longer be restricted to the measurement of medical conditions but start searching for possible causes, making diagnoses and giving practical advice based on the measurement results. Particularly, patients with reduced mobility, people living in areas with little medical infrastructure and those suffering from diseases such as diabetics may benefit from those developments.

However, this chapter also raises a number of questions and challenges which need to be addressed by future research: For example, it should be examined how proper diagnosis and suitable recommendations can be made on the basis of measurement results and how accurate these diagnoses are. Furthermore, the potential benefits and fields of application of these technologies for hospitals and medical staff should be evaluated. Future research should also focus on subsequent development of technologies for the detection of infectious diseases. Developing countries with insufficient health services would benefit most from an extensive, fast and cost-efficient detection of infectious diseases.

Great challenges are expected particularly in the legal field. Regulations for security and privacy of patient data and exchange of sensible data content between devices and clouds need further discussion.

References

AIDS.gov. (2015). *Stages of HIV infection*. Retrieved December 18, 2016, from https://www.aids.gov/hiv-aids-basics/just-diagnosed-with-hiv-aids/hiv-in-your-body/stages-of-hiv/

American Diabetes Association. (2016). *Checking your blood glucose*. Retrieved December 21, 2016, from http://www.diabetes.org/living-with-diabetes/treatment-and-care/blood-glucose-control/checking-your-blood-glucose.html

American Heart Association. (2014). *Lifestyle changes and cholesterol*. Retrieved December 21, 2016, from https://www.heart.org/HEARTORG/Conditions/Cholesterol/PreventionTreatmentofHighCholesterol/Lifestyle-Changes-and-Cholesterol_UCM_305627_Article.jsp

American Heart Association. (2016a). *What is atrial fibrillation (AFib or AF)?* Retrieved December 17, 2016, from http://www.heart.org/HEARTORG/Conditions/Arrhythmia/AboutArrhythmia/What-is-Atrial-Fibrillation-AFib-or-AF_UCM_423748_Article.jsp

American Heart Association. (2016b). *Why cholesterol matters*. Retrieved December 21, 2016, from http://www.heart.org/HEARTORG/Conditions/Cholesterol/WhyCholesterolMatters/Why-Cholesterol-Matters_UCM_001212_Article.jsp

BMJ. (2016). *Chapter 2. Quantifying disease in populations*. Retrieved December 17, 2016, from http://www.bmj.com/about-bmj/resources-readers/publications/epidemiology-uninitiated/2-quantifying-disease-populations

Browning, G. G., & Gatehouse, S. (1992). The prevalence of middle ear disease in the adult British population. *Clinical Otolaryngology & Allied Sciences, 17*(4), 317–321. Retrieved from https://doi.org/10.1111/j.1365-2273.1992.tb01004.x.

Brumbaugh, A. R., & Mobley, H. L. (2012). Preventing urinary tract infection: Progress toward an effective Escherichia coli vaccine. *Expert Review of Vaccines, 11*(6), 663–676. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22873125%255Cn; http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3498450.

Bundesminiterium für Gesundheit. (2016). *Infektionskrankheiten*. Retrieved December 17, 2016, from http://www.bundesgesundheitsministerium.de/themen/praevention/gesundheitsgefahren/infektionskrankheiten.html

Cambridge Business English Dictionary. (n.d.). *Consumer electronics*. Retrieved December 17, 2016, from http://dictionary.cambridge.org/dictionary/english/consumer-electronics

Cheng, S.-Y., Leonard, J. L., & Davis, P. J. (2010). Molecular aspects of thyroid hormone actions. *Endocrine Reviews, 31*(2), 139–170. Retrieved from http://press.endocrine.org/doi/10.1210/er.2009-0007.

Chopra, R., Chander, A., & Jacob, J. J. (2012). Ocular associations of metabolic syndrome. *Indian Journal of Endocrinology and Metabolism, 16*(Suppl1), S6–S11. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3354923/.

Denzlinger, C. (2014). Leukozytose und Leukopenie rational abklären. *Der Allgemeinarzt*, (10). Retrieved from www.allgemeinarzt-online.de.

Department of Health New York State. (1999). *Basic statistics: About incidence, prevalence, morbidity, and mortality – Statistics teaching tools*. Retrieved October 5, 2016, from https://www.health.ny.gov/diseases/chronic/basicstat.htm

Deutsche Gesellschaft für Hals-Nasen-Ohrenheilkunde und Kopf und Hals-Chirurgie e.V. (2014). Chronisch-mesotympanale Otitis media. *AWMF-Leitlinien*, (017), 1–14.

Deutsche Hochdruckliga e.V. DHL. (2015). B*luthochdruck wirksam bekämpfen*. Retrieved December 17, 2016, from https://www.hochdruckliga.de/bluthochdruck.html

"Digital Contact Lenses Can Transform Diabetes Care." (2016). *Digital contact lenses can transform diabetes care*. Retrieved October 10, 2016, from http://medicalfuturist.com/googles-amazing-digital-contact-lens-can-transform-diabetes-care/

DKG, Deutsche Krebshilfe, & AWMF. (2014). S3-Leitlinie Prävention von Hautkrebs. *AWMF-Leitlinien*, (April), 1–231.

Egger, G., & Dixon, J. (2014). *Beyond obesity and lifestyle: A review of 21st century chronic disease determinants, 2014*. Retrieved from https://www-hindawi-com.pitt.idm.oclc.org/journals/bmri/2014/731685/

Enns, G. (2016). *Metabolic disease*. Retrieved December 17, 2016, from https://www.britannica.com/science/metabolic-disease

Fink, W., & Haidinger, G. (2007). Die Häufigkeit von Gesundheitsstörungen in 10 Jahren Allgemeinpraxis. *ZFA - Zeitschrift Für Allgemeinmedizin, 83*(3), 102–108. Retrieved from http://www.thieme-connect.de/DOI/DOI?10.1055/s-2007-968157.

Geldmacher, H., Biller, H., Herbst, A., Urbanski, K., Allison, M., Buist, A. S., et al. (2008). Die Prävalenz der chronisch obstruktiven Lungenerkrankung (COPD) in Deutschland TT – The prevalence of chronic obstructive pulmonary disease (COPD) in Germany. *Deusche medizinische Wochenschrift, 133*(50), 2609–2614. Retrieved from https://www.thieme-connect.de/DOI/DOI?10.1055/s-0028-1105858.

GfK SE. (2016). *Press release*. Retrieved October 5, 2016, from http://www.gfk.com/global-studies/global-studies-fitness-tracking/

Grundy, S. M. (2005). Diagnosis and management of the metabolic syndrome: An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation, 112*(17), 2735–2752. Retrieved from http://circ.ahajournals.org/cgi/doi/10.1161/CIRCULATIONAHA.105.169404.

Hein, H. (2004). Herz-kreislauferkrankungen und schlafbezogene obstruktive Atmungsstörungen. *Pneumologie*. Reinbek: Dr. Holger Hein. Retrieved from http://www.dr-holger-hein.de/index.php?id=12

Herold, G. (2010). *Innere Medizin 2010*. Köln: Gerd Herold.

Huang, P. L. (2009). A comprehensive definition for metabolic syndrome. *Disease Models & Mechanisms, 2*(5–6), 231–237. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2675814/.

Hummers-pradier, E., & Schiemann, G. (n.d.). *Diagnostik und Therapie der Harnwegsinfekte in der Allgemeinmedizin*. Universitätsmedizin Göttingen.

Jacobi, V., Lehnert, T., & Thalhammer, A. (2009). Pneumonien bei Immunsuppression. *Radiologie Up2date, 9*(04), 359–384. Retrieved from http://www.thieme-connect.de/DOI/DOI?10.1055/s-0029-1215330.

Johns, D. P., Walters, J. A. E., & Walters, E. H. (2014). Diagnosis and early detection of COPD using spirometry. *Journal of Thoracic Disease, 6*(11), 1557–1569. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/25478197.

Koch-Institut, R. (2015). Schätzung der Prävalenz und Inzidenz von HIV-Infektionen in Deutschland, Stand Ende 2014. *Epidemiologisches Bulletin*, (45).

Kraywinkel, K., Bertz, J., Laudi, A., & Wolf, U. (2012). Epidemiologie und Früherkennung häufiger Krebserkrankungen in Deutschland. *Gesundheitsberichterstattung Des Bundes (GBE)*, (3).

Merriam-Webster. (n.d.-a). *Etiology*. Retrieved December 20, 2016, from https://www.merriam-webster.com/dictionary/etiology#medicalDictionary

Merriam-Webster. (n.d.-b). *Infectious disease*. Retrieved December 17, 2016, from https://www.merriam-webster.com/medical/infectious disease.

Merriam-Webster. (2016). *Technology*. Retrieved December 17, 2016, from https://www.merriam-webster.com/dictionary/technology

National Heart, Lung, and Blood Institute. (2014). *What are the signs and symptoms of hemolytic anemia?* Retrieved December 21, 2016, from https://www.nhlbi.nih.gov/health/health-topics/topics/ha/signs

National Heart, Lung, and Blood Institute. (2016). *What is metabolic syndrome?* Retrieved December 17, 2016, from https://www.nhlbi.nih.gov/health/health-topics/topics/ms

National Institute of Mental Health. (n.d.). *What is prevalence?* Retrieved December 17, 2016, from https://www.nimh.nih.gov/health/statistics/prevalence/index.shtml

Neuhauser, H., & Poethko-Müller, C. (2014). Chronische Erkrankungen und impfpräventable Infektionserkrankungen bei Kindern und Jugendlichen in Deutschland: Ergebnisse der KiGGS-Studie - Erste Folgebefragung (KiGGS Welle 1). *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 57*(7), 779–788.

OECD. (2015, September 24). *Healthcare costs unsustainable in advanced economies without reform*. Retrieved December 20, 2016, from http://www.oecd.org/health/healthcarecostsunsustainableinadvancedeconomieswithoutreform.htm

Pai, M., & Filion, K. (2003). *AN OVERVIEW OF MEASUREMENTS IN EPIDEMIOLOGY EXPOSURES Disease Frequency exposure*. http://www.med.mcgill.ca/epidemiology/ebss/resources/Docs/An%20overview%20of%20measurements%20in%20epi_v3_2007.pdf

Pascual, A., & Aranda, A. (2013). Thyroid hormone receptors, cell growth and differentiation. *Biochimica et Biophysica Acta (BBA) - General Subjects, 1830*(7). Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0304416512000852.

Penzel, T., Peter, H., & Hermann, J. (2005). Schlafstörungen. *Gesundheitsberichterstattung Des Bundes (GBE), 27*, 49.

Piper, W. (2013). *Innere Medizin* (2nd ed.). Heidelberg: Springer Medizin.

Porta, M. (1995). *A dictionary of epidemiology* (3rd edit ed.). New York: Oxford University Press. Retrieved from file://www.oxfordreference.com/10.1093/acref/9780195314496.001.0001/acref-9780195314496.

Prinz, C., & Ott, I. (2012). Basiswissen Innere Medizin. In L. Dittgen, J. Gaa, U. Henke-Luedecke, I. Ott, F. Schneller, & A. Umgelter (Eds.), *Basislehrbuch Innere Medizin* (1st ed.). Heidelberg: Springer Medizin Verlag.

Riffelmann, M., Littmann, M., Hellenbrand, W., Hülße, C., & Wirsing von König, C. H. (2008). Pertussis - nicht nur eine Kinderkrankheit. *Dtsch. Ärztebl, 105*(37), 623–628. Retrieved from http://www.aerzteblatt.de/v4/archiv/artikel.asp?src=suche&id=61447%5CnC:%5CKarsten%5CPDFs%5CBakteriologie-PDFs%5CBakt-2008%5CRiffelmann et al.-Pertussis - nicht nur eine Kinderkrankheit.pdf.

Rober Koch-Institut. (n.d.). *Cardiovascular disease*. Retrieved December 17, 2016, from http://www.rki.de/EN/Content/Health_Monitoring/Main_Topics/Chronic_Disease/Cardiovascular_Disease/cardiovascular_disease_node.html

Robert Koch-Institut. (2009). *Streptococcus pyogenes-Infektionen*. Retrieved December 17, 2016, from https://www.rki.de/DE/Content/Infekt/EpidBull/Merkblaetter/Ratgeber_Streptococcus_pyogenes.html

Robert Koch-Institut. (2014a). *Keuchhusten (Pertussis)*. Retrieved December 17, 2016, from https://www.rki.de/DE/Content/Infekt/EpidBull/Merkblaetter/Ratgeber_Pertussis.html#doc2374534bodyText3

Robert Koch-Institut. (2014b). *Koronare Herzkrankheit. Faktenblatt zu GEDA 2012: Ergenisse der Studie >>Gesundheit in Deutschland aktuell 2012<<.*

Robert Koch-Institut. (2015a). *Faktenblatt zu DEGS1 : Studie zur Gesundheit Erwachsener in Deutschland (2008–2011) Prävalenz von Diabetes mellitus*. Berlin.

Robert Koch-Institut. (2015b). *Health in Germany*. *Federal Health Reporting. Joint service by RKI and Destatis. RKI, Berlin*.

Robert Koch-Institut. (2016a). Epidemiologisches Bulletin. *Epidemiologisches Bulletin, 38*, 177–186. Retrieved from http://www.rki.de/DE/Content/Infekt/EpidBull/Archiv/2015/Ausgaben/15_15.pdf?__blob=publicationFile.

Robert Koch-Institut. (2016b). *HIV-infektion/AIDS*. Retrieved December 17, 2016, from https://www.rki.de/DE/Content/Infekt/EpidBull/Merkblaetter/Ratgeber_HIV_AIDS.html#doc2374480bodyText9

Robert Koch-Institut. (2016c). *Windpocken, Herpes zoster (Gürtelrose)*. Retrieved December 18, 2016, from https://www.rki.de/DE/Content/Infekt/EpidBull/Merkblaetter/Ratgeber_Varizellen.html

Robert Koch-Institut, & Destatis. (2015). Gesundheit in Deutschland (2015). *Gesundheitsberichterstattung Des Bundes*, 13–76.

Saliba, W., Nitzan, O., Chazan, B., & Elias, M. (2015). Urinary tract infections in patients with type 2 diabetes mellitus: review of prevalence, diagnosis, and management. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 8*, 129. Retrieved from http://www.dovepress.com/urinary-tract-infections-in-patients-with-type-2-diabetes-mellitus-rev-peer-reviewed-article-DMSO.

Sandru, A., Voinea, S., Panaitescu, E., & Blidaru, A. (2014). Survival rates of patients with malignant melanoma. *Journal of Medicine and Life, 7*(4), 572–576.

Schnabel, R. (2012). Vorhofflimmern und Schlaganfallrisiko in der Allgemeinbevölkerung. In *German Cardiac Society Web Presence*. Hamburg: Deutsche Gesellschaft für Kardiologie – Herz- und Kreislaufforschung e.V. (DGK).

Schuchert, A., Gerth, A., Näbauer, M., Steinbeck, G., & Meinertz, T. (2005). Vorhofflimmern Epidemiologie, Klinik und Prognose. *Med Welt*, 361–365. Retrieved from www.die-medizinische-welt.de.

Schulz, S., Freitag, M., & Gensichen, J. (2012). Schilddrüsenerkrankungen in der Hausarztpraxis. *Ärzteblatt Thüringen, 23*(9), 468–471.

Sharma, M., & Majumdar, P. K. (2009). Occupational lifestyle diseases: An emerging issue. *Indian Journal of Occupational and Environmental Medicine, 13*(3), 109–112. https://doi.org/10.4103/0019-5278.58912.

Sondak, V. K., & Smalley, K. (2009). Targeting mutant BRAF and KIT in metastatic melanoma: ASCO 2009 meeting report. *Pigment Cell & Melanoma Research, 22*(4), 386–387. Retrieved from http://doi.wiley.com/10.1111/j.1755-148X.2009.00593.x.

Thacker, S. B., Stroup, D. F., Carande-Kulis, V., Marks, J. S., Roy, K., & Gerberding, J. L. (2006). Measuring the public's health. *Public Health Reports, 121*(1), 14–22.

Thomas, J. P., Berner, R., Zahnert, T., & Dazert, S. (2014). Acute otitis media–a structured approach. *Deutsches Ärzteblatt International, 111*(9), 151–159; quiz 160. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3965963&tool=pmcentrez&rendertype=abstract%5Cn; http://www.ncbi.nlm.nih.gov/pubmed/24661591%5Cn; http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3965963.

Tschäpe, H. (2000). Lebensmittelbedingte Infektionskrankheiten durch Bakterien. *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 43*(10), 758–769. Retrieved from http://link.springer.com/10.1007/s001030050353.

U.S. Department of Health and Human Services. (2000). Healthy People 2010: Understanding and Improving Health. Washington, DC: US Government Printing Office, November 2000. In *Book US Department of Health and Human Services. Healthy People 2010: Understanding and Improving Health* (Vol. 1, 2nd ed.). Washington, DC: U.S. Government Printing Office.

Vorvick, L. J. (2015a). *Invasive*. Retrieved December 17, 2016, from https://medlineplus.gov/ency/article/002384.htm

Vorvick, L. J. (2015b). *Noninvasive*. Retrieved December 17, 2016, from https://medlineplus.gov/ency/article/002269.htm

Wächtler, H., & Chenot, J.-F. (2011). Die Halsschmerz-Leitlinie der Deutschen Gesellschaft für Allgemeinmedizin und Familienmedizin. *HNO, 59*(5), 480–484. Retrieved from http://link.springer.com/10.1007/s00106-011-2263-6.

Wagenlehner, F. M. E. (2015). *Urinary tract infections epidemiology and management strategies*. Gießen: Clinic for Urology, Pediatric Urology and Andrology Universitätsklinikum Gießen.

Wagner, K., & Sparr, F. J. (2012). *Wie kann die Gesundheitskompetenz in der Bevölkerung verbessert werden?* Linz.

Where No Healthcare Device Has Gone Before. (2015). *The Pathologist*, (June).

Willett, W. C., Koplan, J. P., Nugent, R., Dusenbury, C., Puska, P., & Gaziano, T. A. (2006). Prevention of chronic disease by means of diet and lifestyle changes. In *Disease control priorities in developing countries* (pp. 833–850). Oxford University Press. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21250366.

Williamson, R. T. (2009). Causes of diabetes. *The Practitioner, 253*(1718), 37.

Wirth, A., Pfeiffer, A., Steinmetz, A., Albus, C., Bjarnason-Wehrens, B., Cordes, C., et al. (2006). Das Metabolische Syndrom - Empfehlungen für die kardiologische Rehabilitation. *Herzmedizin, 23*(4), 187–196.

World Health Organization. (n.d.). *Global burden of disease*. Retrieved December 18, 2016, from http://www.who.int/topics/global_burden_of_disease/en/

World Health Organization. (2008). Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bulletin of the World Health Organization, 86*(2), 81–160. Retrieved from http://www.who.int/bulletin/volumes/86/2/07-040089/en/.

World Health Organization. (2009). *Self-care in the context of primary health care*. Report of the World Health Organization Regional Consultation Bangkok, Thailand, 7–9 January 2009.

World Health Organization. (2010). *International statistical classification of diseases and related health problems* (10th ed.). World Health Organization.

World Health Organization. (2016a). *Cardiovascular diseases (CVDs)*. Retrieved December 17, 2016, from http://www.who.int/mediacentre/factsheets/fs317/en/

World Health Organization. (2016b). Global Report on Diabetes. In: G. Roglic. World Health Organization. 86.

World Health Organization. (2016c). *Global report on diabetes* (Vol. 978). Retrieved from http://www.who.int/about/licensing%5Cn; http://apps.who.int/iris/bitstream/10665/204871/1/9789241565257_eng.pdf

World Health Organization. (2016d). *Metrics: Disability-Adjusted Life Year (DALY)*. Retrieved October 5, 2016, from https://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/