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# Digital Health Interventions (DHIs) to Support the Management of Children and Adolescents with Sickle-Cell Disease

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Stephan Lobitz, Kristina Curtis and Kai Sostmann

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<http://dx.doi.org/10.5772/64315>

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## Abstract

Sickle-cell disease (SCD) is a very complex disorder alluding to all areas of medicine. Nevertheless, basic preventive and therapeutic interventions in patients suffering from SCD are extremely simple. However, in everyday life it is sometimes virtually impossible to motivate children and young adolescents to effectively self-manage their disorder at an early stage. Digital health interventions (DHIs) provide new opportunities to support self-management behaviours. DHIs may facilitate daily and recurrent routines such as drug intake or appointments along with helping the patients to better cope with their disease. This may be realized through mobile-training programmes, disease-specific social networks using secure communication channels, diaries, blogs and even games. Indeed, there are fascinating opportunities for modern disease-training programmes to take advantage of several media that can be combined and didactically optimized to meet the individual needs and intellectual abilities of different patients. The technological progress is rapid, extremely dynamic and highly creative. Our chapter gives an overview of the multifarious world of DHIs with a focus on smartphone applications known as mobile health apps (mHealth apps). We elucidate the potential reasons why we think that numerous apps for SCD patients have not been successful and which app features developers should consider if they want to create a popular patient app.

**Keywords:** mHealth, smartphone application, app, DHI, sickle-cell disease

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## 1. Introduction

The rapid technological progress of the last two decades has had a deep impact on medical practice and research. In particular, searching for health information has become significantly

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easier today compared to the last few decades, where it was necessary to visit a library or a bookstore to access a certain publication. Today, health information is just a mouse-click away. You can download it to your computer, tablet or smartphone at any place in the world provided you are connected to the Internet. The latest scientific health evidence, therapies and guidelines to name but a few can be spread at lightning speed.

Health communication itself has been profoundly revolutionized in many ways. Undeniably, previous forms of communication such as letters and faxes have been largely replaced by mobile phones in the form of text, photo and video messaging. In particular, the smartphone plays a crucial role. Smartphones are a combination of a mobile phone and a personal digital assistant (PDA), often combined with inbuilt sensors such as accelerometers, cameras and GPS. They are generally categorized by their manufacturer or operating system (OS) with the most prevalent systems running on Android, iOS, Windows phone and Blackberry OS platforms [1, 2]. Smartphones enable people to exchange information around the world in a matter of seconds. This offers considerable advantages to both patients and health-care staff, and hence health-care providers should be open-minded towards this rapid and continuous stream of information. Ultimately, these new technologies have the potential capability to improve patient care significantly. However, any concrete application requires a very critical assessment, in particular in terms of usefulness and data security, since many applications may not keep their promises and potentially cause more harm than good [3–7]. Although it should be noted that no digital application in the world replaces the personal contact between the patient and the doctor, some may support this sensitive relationship in a reasonable and timely manner. This may help to make daily routines easier and save considerable resources in a time of underfinanced health-care systems.

This chapter provides an introduction to the multifarious and versatile world of digital health interventions with a focus on smartphone applications ('apps') for patients with sickle-cell disease (SCD).

## 2. Digital health interventions (DHIs)

DHIs are composed of software solutions on personal computers, mobile phones or tablets and, finally, web-based resources. DHIs are synonymously used with the term 'eHealth' and comprise a wide range of technologies and health conditions. The World Health Organization (WHO) classifies DHIs into the following categories [8]:

- The delivery of health information, for health professionals and health consumers, through the Internet and telecommunications.
- Using the power of IT and e-commerce to improve public health services, for example, through the education and training of health workers.
- The use of e-commerce and e-business practices in health system management.

Digital health technologies may involve tools that help to support the management of particular health conditions. For example, the miniaturization of sensor technology for use in mobile devices allows for the recognition and recording of motion patterns with increasing accuracy and permitting non-invasive synchronization with a multitude of bodily functions such as heart rate, blood pressure, perspiration, facial expression or haemoglobin levels. Invasively measured data can be entered manually for the purpose of documentation (e.g. blood glucose) [9–16]. Automated interpretation of the data entered by the software allows for an immediate feedback to the user. The technological progress is rapid, extremely dynamic and highly creative.

Along with simple tasks such as the documentation of pharmacotherapy or reminders of appointments, modern devices may also monitor correct drug intake, for example, by reading barcodes on the drug package with the smartphone's inbuilt camera. Motion sensors help to achieve predefined daily activity goals or detect patterns typical of certain disease states or complications such as pain. The presence and immediate availability of mobile devices enable their user to keep records at any time and place—an exciting feature in terms of documenting the natural history of a disease in a patient and of particular interest in clinical research.

DHI providers and users are able to interact by means of diverse forms of text, picture and video messaging. There are also fascinating opportunities for modern disease-training programmes to combine several media that can be didactically optimized for the individual needs and intellectual abilities of a range of patients. Video conferences between patients and doctors may help to facilitate real-time exchange of information and medical findings, even between individuals who live thousands of miles away from each other. This is a highly beneficial feature monitoring injuries and symptoms such as wounds or skin rashes.

Currently, there is a trend in developing DHIs to help modify behaviour [17]. In the majority of cases, these DHIs are smartphone applications that can be easily adapted to the individual needs. Many of them are health promoting and preventive in character and aim to support users to start or reinforce one of more health behaviours (e.g. health eating) and/or reduce risk behaviours (e.g. smoking cessation) [18]. The majority of these apps are aimed at healthy people, but not for patients—developing a huge market.

### **2.1. Mobile health apps**

One of the most important sub-disciplines of DHIs is mobile health (mHealth), outlined by the Global Observatory of eHealth (GOe) as mobile devices such as mobile phones, personal digital assistants (PDA), and other wireless devices supporting medical or public health routines [19]. mHealth interventions can be structured into eight categories [2]:

- point-of-care diagnostics
- wellness
- education and reference
- efficiency and productivity

- patient monitoring
- compliance
- behaviour modification
- environmental mentoring

Within mHealth, it is the arrival of the smartphone, complemented by an eruption of commercial mobile health and medical apps (mHealth apps), that is revolutionizing approaches to personal health management [20]. A mobile app is a small programme or application downloaded from a website (e.g. Apple's App Store) which operates on a smartphone or a tablet computer [1, 2]. Originally, apps have served to improve productivity (e.g. a simple calendar app) or handle small data sets and information (e.g. phone book). However, as a result of a tremendous demand, mobile apps for smartphones and tablets have been developed for use in all areas of life. Inevitably, the app market has grown exponentially within the last years. By 2016, it is expected that over 44 billion apps will have been downloaded which equates to six apps downloaded for every person across the globe [21].

Currently, the two big app stores, the Apple App Store and the Google Play Store, host more than 150,000 health apps, ready to be downloaded and claiming to provide a health-promoting benefit for the user or an entrusted person. Approximately 20,000 apps are medical apps in a strict sense, that is, they are directed to patients, doctors and other medical service providers with the ultimate goals of supporting medical care [7].

The global sales volume of mobile health technologies is expected to reach 31 billion Euros by 2020 [22], creating a highly competitive market. The wide choice of products generates a trade rivalry of formerly unknown enormity resulting in many apps being discarded after first use. Indeed, the consumer decides whether an app will survive or not, although it is important to recognize that even well-liked apps are thought to have a life expectancy of less than 6 months. Many factors are important when considering what makes a 'good' app. Many of which are intangible, that is, factors that affect the decision, but that cannot be expressed in monetary or rational terms. Is an app useful? Is it easy to handle? Is it self-explanatory? Is it visually appealing? The decision on success or failure depends on nuances. Ultimately, it is difficult to predict how certain population groups will respond to a health app. However, a range of sub-disciplines from the design, psychology, engineering and computer science fields seeks to understand the nature of app usage. Among these fields, there is strong consensus that app development requires drawing on theory, evidence and formative research with the target audience. Mobile health interventions should have a high degree of social validity and acceptability among its users, helping to establish the trend towards the adoption of a user-centred approach [23]. User-Centred Design (USD) places the users' needs and desires at the core of the development process. It represents a participatory design approach focusing on the user and on 'incorporating the user's perspective in all stages of the design process' [24].

### 3. Wearables

Further developments in the field of mobile interactive devices comprise the introduction of so-called wearable electronic devices ('wearables'). Most of these microelectronic items are at the size of a wrist watch or so small that they can be delivered on the size of a credit card or as a piece of jewellery. They are developed mainly to measure and deliver data in real time or to record long-term data. Sensors of these items can track the activity, velocity and the location of their users (GPS, accelerometers, speedometers). Other sensor technology measures physical functions such as heart frequency rates, oxygen saturation in the blood, blood pressure or skin humidity. They are applied at two levels to the health-care market. On the consumer side of the market, the distribution of these items exploded and founded a market on its own, where there has been a drive towards people measuring every aspect of their physical and mental life known as the 'Quantified Self-Movement' [25]. Within the context of the health-care system, data collection is fundamental to the improvement of health-care services for patients with SCD. The collection, analysis and interpretation of data enabled through the application of recently developed new software technologies have led to a new discipline known as 'Big Data'. The sheer volume of patient data represents new opportunities and new challenges for multiple stakeholders regarding data storage and interpretation.

### 4. Digital health interventions (DHIs) for SCD

Sickle-cell disease is a very complex disorder alluding to virtually all areas of medicine. Nevertheless, basic preventive and therapeutic interventions in patients suffering from SCD are extremely simple. Minor behavioural changes may reduce the incidence of several complications. Wearing warm clothes prevents pain crises. Vaccinations and penicillin prophylaxis virtually eliminate life-threatening bacterial infections. Patients with febrile illnesses require urgent medical care. Parents who are able to palpate spleen size can diagnose splenic sequestration at home at a very early stage and seek medical attention immediately. Most patients who have internalized this simple code of conduct show a great improvement in their condition.

The groundwork is laid in childhood. It is up to the paediatricians to communicate this information and knowledge during childhood and adolescence. Experience has taught us that the transition to adult care is often inadequate and that those patients who get lost at this critical stage of care have not understood the gravity of their individual situation—resulting in serious consequences for their health.

However, in everyday life it is sometimes virtually impossible to support children and adolescents to self-manage their condition. For the first time ever, DHIs provide new opportunities to support self-management behaviours [26, 27]. As a minimum, DHIs may facilitate daily and recurrent routines such as drug intake or appointments through simple reminders. However, at an advanced level, they may also help the patient to cope better with their disease.

This may be realized through a number of modes of delivery such as mobile-training programmes, disease-specific social networks using secure communication channels, diaries and blogs.

It is an absolute prerequisite to awaken a patient's interest and motivation in their own disease to establish understanding and create awareness for disease-specific needs. DHIs, in particular apps, for children and adolescent with SCD aim to create an improved sense of self and disease in the very first instance.

Despite the enormous prevalence of SCD, there are still a limited number of SCD apps available to patients suffering from SCD, their families, peers and caregivers as well as a paucity of publications on SCD apps. Nevertheless, so far research has shown promise for the acceptability and usability of SCD apps aimed at tracking multiple symptoms such as pain and tiredness [28–30], facilitating reminders for medication [31], enhancing communication with health-care providers and general health management [30] and delivering therapeutic interventions such as cognitive behavioural therapy [32, 33]. Indeed, research- and industry-led apps have chosen diverse approaches to address SCD. Consequently, the diverging SCD-related apps on the market pursue a variety of objectives. Most apps have several functions and behavioural targets, but they can be classified on the basis of their primary objective.

There are apps that:

- facilitate the diagnosis of SCD
- help to educate patients about the disease
- record symptoms and complications
- aim to change the behaviour of patients, in particular, their adherence to medication
- support therapeutic approaches to coping with the disease
- improve the communication between patients and between patients and caregivers

A number of SCD apps have been developed by academic institutions or pharmaceutical companies, while other apps are the product of more or less fruitful cooperation between different stakeholders. However, most app developers fail to involve patients in the design, development or evaluation process. Consequently, most apps for SCD patients have one feature in common: they have been rejected by the patient community and disappeared rapidly from the market.

## 5. Identifying the gaps in SCD apps: the case of Germany

The clinical course of an individual suffering from SCD is highly dependent on where the patient actually lives. For example, there are massive problems in providing state-of-the-art care in most African countries. Many patients have none or limited access to public health care.

In addition, most health-care systems in Africa where many drugs are not widely available are not comparable to the high-resource countries in Europe and North America. In particular, most patients in Africa have no access to penicillin prophylaxis and to hydroxycarbamide despite the fact that the latter is comparatively cheap and on the WHO Model List of Essential Medicines [34]. Additional adverse factors such as malaria and malnutrition also have a high impact on the outcome of SCD in Africa. Consequently, regionally up to 90% of children suffering from SCD die before they are 5 years of age [35]. In the second decade of the twenty-first century, this is horrifying. In stark comparison, during the last four decades, SCD care has improved considerably in Europe and North America. Newborn screening, infection prophylaxis and the wide use of hydroxyurea have probably had the most important impact on the survival rates that are now close to 100% in childhood and adolescence in the large cohort studies from the UK and USA, respectively [36–40].

However, the quality of care for patients suffering from SCD is not only dependent on the unlimited access to an efficient health-care system and medication. It is also dependent on national and local prevalence rates and the comprehensiveness of care centres for the treatment of SCD and other disorders. Globally, SCD is the most common monogenetic disease of all, a fact that is mainly attributed to its high prevalence in Sub-Saharan Western and Central Africa, the Persian Gulf and India. SCD is quite uncommon in the Middle and Northern European countries and actually even fulfils the criteria of a rare disease in most European countries. The European Medicines Agency's (EMA) definition of a rare disease is 'less than five affected persons in 10,000'. Consequently, many countries with high-performance health-care systems (such as Germany) have problems in offering comprehensive SCD care, simply because they do not have enough patients in most centres. It took the German Society of Paediatric Oncology and Haematology (GPOH) until 2012 to implement a structured disease-management program and to establish a national registry for patients with SCD. A national guideline for the treatment of children and adolescents with SCD was released in 2015. And finally, three pilot studies have shown that the prevalence of SCD in Germany is high enough to justify integrating the highly political SCD-screening procedure into the national newborn screening programme [41–44].

Although the number of SCD in Germany is expected to be in an order of 3000–5000 (estimate based on personal communications and reference [45]), 58 GPOH hospitals, several non-GPOH hospitals and a number of paediatricians in private practice are involved in primary SCD care. Consequently, most doctors look after much less than 30 patients. And unfortunately, there are no prominent patient-support groups.

Another important aspect is that in Germany, SCD only affects people with a personal or a familial history of migration [45]. In the majority of cases, patients are poorly integrated and have a poor educational background. Their influence on the society is low and so is their impact on political decisions. In other words, they have no voice.

Accordingly, it is difficult to acquire funding for clinical research and development for patients suffering from SCD. Not even clinical routine care is financed adequately. For example, the German compulsory health insurance companies do not cover liver iron MRI examinations for



polytransfused patients on a reliable legal basis. Decisions are made on a case-by-case basis and require a yearly time-consuming formal application for each individual.

The main problems in Germany are summarized as follows:

- no dedicated treatment centre(s) for haemoglobinopathies
- few specialized contact persons
- poor utilization of present resources
- poor knowledge about the disease among the patient population
- low levels of awareness and virtually no knowledge about the disease among the general population
- poor education levels of most patients and their families
- little willingness towards understanding the 'basics' of the disease in conjunction with a suboptimal support from the health-care providers

Within the context of Germany, a smartphone application for SCD patients requires app features to:

- improve the patient's interest in his/her own illness, hopefully leading to a better understanding of sickle-cell disease,
- support the patient in taking their medication (improve adherence),
- improve appointment adherence,
- improve the documentation of complications and other disease-related symptoms to get a more objective overall picture of the individual clinical course between two consultations,
- improve the communication with the health-care service providers,
- improve the communication between patients,
- educate the surrounding family and community about the condition,
- support the patients whenever and wherever they are looking for a doctor specialized in SCD care, in particular when they are not at home (e.g. on a holiday).

Certainly, these objectives may differ from other countries where there may already be well-working educational programmes in place. However, there is strong consensus among some health-app developers, that the needs defined by doctors differ significantly from the needs defined by patients. It is thus an indispensable prerequisite to develop a successful app to involve patients into the whole development process right from the start [26]. To keep the balance between the patients' and doctors' needs is the 'art of health-app development'.

## Author details

Stephan Lobitz<sup>1\*</sup>, Kristina Curtis<sup>2</sup> and Kai Sostmann<sup>3</sup>

\*Address all correspondence to: [stephan.lobitz@charite.de](mailto:stephan.lobitz@charite.de)

1 Department of Pediatric Oncology, Hematology and BMT, Charité-University Medicine Berlin, Berlin, Germany

2 The Centre for Technology Enabled Health Research (CTEHR), Coventry University, Coventry, United Kingdom

3 Department of eLearning, Vice Deanery for Academic Studies and Teaching, Charité – University Medicine Berlin, Berlin, Germany

## References

- [1] Curtis, K.E., The development of a theory and evidence based, user-centred family healthy eating app in The University of Warwick. 2016.
- [2] Olla, P. and Shimskey, C., mHealth taxonomy: a literature survey of mobile health applications. *Health Technol*, 2014. 4: p. 299–308.
- [3] Wolf, J.A., et al., Diagnostic inaccuracy of smartphone applications for melanoma detection. *JAMA Dermatol*, 2013. 149(4): p. 422–426.
- [4] Wallace, L.S. and Dhingra, L.K., A systematic review of smartphone applications for chronic pain available for download in the United States. *J Opioid Manag*, 2014. 10(1): p. 63–68.
- [5] Baig, M.M., GholamHosseini, H. and Connolly, M.J., Mobile healthcare applications: system design review, critical issues and challenges. *Australas Phys Eng Sci Med*, 2015. 38(1): p. 23–38.
- [6] BinDhim, N.F., Hawkey, A. and Trevena, L., A systematic review of quality assessment methods for smartphone health apps. *Telemed J E Health*, 2015. 21(2): p. 97–104.
- [7] Wiechmann, W., et al., There's an app for that? Highlighting the difficulty in finding clinically relevant smartphone applications. *West J Emerg Med*, 2016. 17(2): p. 191–194.
- [8] WHO Trade foreign policy diplomacy and health E-Health 2016; Available from: <http://www.who.int/trade/glossary/story021/en/>
- [9] Collings, S., et al., Non-invasive detection of anaemia using digital photographs of the conjunctiva. *PLoS One*, 2016. 11(4): p. e0153286.

- [10] Kim, E.K., et al., Feasibility of a patient-centered, smartphone-based, diabetes care system: a pilot study. *Diabetes Metab J*, 2016.
- [11] Franc, S., et al., Telemedicine and type 1 diabetes: is technology per se sufficient to improve glycaemic control? *Diabetes Metab*, 2014. 40(1): p. 61–66.
- [12] McGillicuddy, J.W., et al., Mobile health medication adherence and blood pressure control in renal transplant recipients: a proof-of-concept randomized controlled trial. *JMIR Res Protoc*, 2013. 2(2): p. e32.
- [13] Simon, S.K. and Seldon, H.L., Personal health records: mobile biosensors and smartphones for developing countries. *Stud Health Technol Inform*, 2012. 182: p. 125–132.
- [14] Gregoski, M.J., et al., Development and validation of a smartphone heart rate acquisition application for health promotion and wellness telehealth applications. *Int J Telemed Appl*, 2012. 2012: p. 696324.
- [15] Lowres, N., et al., Atrial fibrillation screening in pharmacies using an iPhone ECG: a qualitative review of implementation. *Int J Clin Pharm*, 2015. 37(6): p. 1111–1120.
- [16] Lowres, N., et al., Self-monitoring for atrial fibrillation recurrence in the discharge period post-cardiac surgery using an iPhone electrocardiogram dagger. *Eur J Cardiothorac Surg*, 2016.
- [17] Neubeck, L., et al., The mobile revolution—using smartphone apps to prevent cardiovascular disease. *Nat Rev Cardiol*, 2015. 12(6): p. 350–360.
- [18] Curtis, K.E. and Karasouli, E., An assessment of the potential of health promotion apps to support health behaviour change. *Health Psychol Update*, 2014. 23(2): p. 43–49.
- [19] WHO, mHealth: new horizons for health through mobile technologies. *Global Observatory for eHealth Series*, 2011. 3; Available from: [http://www.who.int/goe/publications/ehealth\\_series\\_vol3/en/](http://www.who.int/goe/publications/ehealth_series_vol3/en/).
- [20] Bert, F., et al., Smartphones and health promotion: a review of the evidence. *J Med Syst*, 2014. 38(1): p. 9995.
- [21] West, J.H., et al., Health behavior theories in diet apps. *J Cons Health Int*, 2013. 17(1): p. 10–24.
- [22] Vranova, Z., The mHealth app market will grow by 15% to reach \$31 billion by 2020. 2016; Available from: <http://research2guidance.com/2015/11/11/the-mhealth-app-market-will-grow-by-15-to-reach-31-billion-by-2020/>.
- [23] Curtis, K.E., Lahiri, S. and Brown, K.E., Targeting parents for childhood weight management: development of a theory-driven and user-centered healthy eating app. *JMIR Mhealth Uhealth*, 2015. 3(2): p. e69.

- [24] Devi, K.R., Sen, A.M. and Hemachandran, K., A working framework for the user-centered design approach and a survey of the available methods. *Int J Sci Res Publ*, 2012. 2(4): p. 1–8.
- [25] Appelboom, G., et al., The quantified patient: a patient participatory culture. *Curr Med Res Opin*, 2014. 30(12): p. 2585–2587.
- [26] Badawy, S.M., Thompson, A.A. and Liem, R.I., Technology access and smartphone app preferences for medication adherence in adolescents and young adults with sickle cell disease. *Pediatr Blood Cancer*, 2016. 63(5): p. 848–852.
- [27] Issom, D.Z., et al., Exploring the challenges and opportunities of ehealth tools for patients with sickle cell disease. *Stud Health Technol Inform*, 2015. 216: p. 898.
- [28] Jacob, E., et al., Remote monitoring of pain and symptoms using wireless technology in children and adolescents with sickle cell disease. *J Am Assoc Nurse Pract*, 2013. 25(1): p. 42–54.
- [29] Jonassaint, C.R., et al., Usability and feasibility of an mhealth intervention for monitoring and managing pain symptoms in sickle cell disease: the sickle cell disease mobile application to record symptoms via technology (SMART). *Hemoglobin*, 2015. 39(3): p. 162–168.
- [30] Shah, N., Jonassaint, J. and De Castro, L., Patients welcome the sickle cell disease mobile application to record symptoms via technology (SMART). *Hemoglobin*, 2014. 38(2): p. 99–103.
- [31] Creary, S.E., et al., A pilot study of electronic directly observed therapy to improve hydroxyurea adherence in pediatric patients with sickle-cell disease. *Pediatr Blood Cancer*, 2014. 61(6): p. 1068–1073.
- [32] Cheng, C., et al., iACT--an interactive mHealth monitoring system to enhance psychotherapy for adolescents with sickle cell disease. *Conf Proc IEEE Eng Med Biol Soc*, 2013. 2013: p. 2279–2282.
- [33] Schatz, J., et al., Changes in coping, pain, and activity after cognitive-behavioral training: a randomized clinical trial for pediatric sickle cell disease using smartphones. *Clin J Pain*, 2015. 31(6): p. 536–547.
- [34] McGann, P.T., et al., Hydroxyurea therapy for children with sickle cell anemia in sub-saharan africa: rationale and design of the REACH trial. *Pediatr Blood Cancer*, 2016. 63(1): p. 98–104.
- [35] Grosse, S.D., et al., Sickle cell disease in Africa: a neglected cause of early childhood mortality. *Am J Prev Med*, 2011. 41(6 Suppl 4): p. S398–S405.
- [36] Elmariah, H., et al., Factors associated with survival in a contemporary adult sickle cell disease cohort. *Am J Hematol*, 2014. 89(5): p. 530–535.

- [37] Quinn, C.T., et al., Improved survival of children and adolescents with sickle cell disease. *Blood*, 2010. 115(17): p. 3447–3452.
- [38] Wierenga, K.J., Hambleton, I.R. and Lewis, N.A., Survival estimates for patients with homozygous sickle-cell disease in Jamaica: a clinic-based population study. *Lancet*, 2001. 357(9257): p. 680–683.
- [39] Lee, A., et al., Improved survival in homozygous sickle cell disease: lessons from a cohort study. *BMJ*, 1995. 311(7020): p. 1600–1602.
- [40] Telfer, P., et al., Clinical outcomes in children with sickle cell disease living in England: a neonatal cohort in East London. *Haematologica*, 2007. 92(7): p. 905–912.
- [41] Lobitz, S., et al., Incidence of sickle cell disease in an unselected cohort of neonates born in Berlin, Germany. *Eur J Hum Genet*, 2014. 22(8): p. 1051–1053.
- [42] Frommel, C., et al., Newborn screening for sickle cell disease: technical and legal aspects of a German pilot study with 38,220 participants. *Biomed Res Int*, 2014. 2014: p. 695828.
- [43] Kunz, J.B., et al., Significant prevalence of sickle cell disease in Southwest Germany: results from a birth cohort study indicate the necessity for newborn screening. *Ann Hematol*, 2016. 95(3): p. 397–402.
- [44] Grosse, R., et al., The prevalence of sickle cell disease and its implication for newborn screening in Germany (Hamburg metropolitan area). *Pediatr Blood Cancer*, 2016. 63(1): p. 168–170.
- [45] Kohne, E. and Kleihauer, E., Hemoglobinopathies: a longitudinal study over four decades. *Dtsch Arztebl Int*, 2010. 107(5): p. 65–71.