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DISSERTATION

School Careers of Children with Congenital Heart Disease

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Preface

Partial findings of this monography have previously been published:

"Educational achievement of children with congenital heart disease: Promising results from a survey by the German National Register of Congenital Heart Defects"
Pfitzer, Helm, Blickle, Rosenthal, Berger, Abdul-Khaliq H, Bauer UMM, Schmitt KRL
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Abstract English

Objectives: We analysed the upbringing and school careers of children, adolescents and young adults diagnosed with a congenital heart disease (CHD) in Germany.

Method: A cross-sectional study was conducted using an online survey. The recruitment of study participants was carried out via the database of the German National Register for Congenital Heart Disease (NRCHD). Patients born between 1992 and 2011 were enrolled in the study. We compared our results to the general population with census data from the German Federal Statistics Office.

Results: 3,605 people participated in the survey and out of these, 2,901 (80.5%) completed the questionnaire. Detailed information regarding the underlying CHD diagnosis as well as clinical data from medical records was available for 2,609 (72.4%) patients. The overwhelming majority of patients were enrolled at a normal elementary school (83.4%). Patients were predominantly enrolled at the age of six or younger (74.6%) which is similar to the general population (64%). 83.0% of patients with a mild, 74.3% of patients with a moderate and 68.2% of patients with a severe CHD were enrolled at the age of six or younger. 45.7% of the graduated study participants had acquired the qualifications to study at university ("Abitur"). School careers varied significantly among the different CHD severity subgroups. When analysing all graduated participants 57.3% of mild, 47.3% of moderate and 35.1% of severe CHD patients attained the general university admission qualifications.

CHD patients frequently suffered from psychological or behavioural disorders (33.3%) and often had to repeat a school year (11.2%). The highest incidence of psychiatric disorders was reported in patients with severe CHDs. These patients most often had to repeat a school year.

Conclusions: In our study, the majority of participating CHD patients had a standard school career. These initial results are of great importance to affected families and treating physicians as they can alleviate parents' fears by showing that a normal school career is possible for patients diagnosed with a CHD. Nevertheless, school form and age at enrolment and the final school degree attained varied depending on the severity of the underlying CHD. Patients were more likely to be diagnosed with a psychological disorder and/or forced to repeat a class if their CHD was more severe. Therefore, better systems are required to identify at-risk patients to enable early interventional therapy.

Abstrakt Deutsch

Ziele: Wir analysierten die schulische Entwicklung von Kindern, Jugendlichen und jungen Erwachsenen mit der Diagnose eines angeborenen Herzfehlers (AHF) in Deutschland.

Methoden: Mittels einer Online-Befragung wurde eine Querschnittsstudie durchgeführt. Die Studienteilnehmer wurden über die Datenbank des Nationalen Registers für angeborene Herzfehler (NRAHF) rekrutiert. Zwischen 1992 und 2011 geborene Patienten wurden in die Studie eingeschlossen. Wir verglichen unsere Ergebnisse mit der Allgemeinbevölkerung mit Hilfe von Daten des Statistischen Bundesamtes.

Ergebnisse: 3.605 Personen nahmen an der Studie teil, von denen 2.901 (80,5%) die Umfrage vollständig ausfüllten. Ausführliche Informationen über den zugrundeliegenden AHF sowie klinische Daten aus Krankenhausakten lagen für 2.609 (72,4%) Patienten vor. Die Mehrheit der Patienten besuchte eine normale Grundschule (83,4%). Die Patienten wurden überwiegend im Alter von 6 Jahren oder jünger (74,6%) eingeschult, in einem vergleichbaren Alter zur Allgemeinbevölkerung (64%). 83% der Kinder mit leichtem, 74,3% mit moderatem und 68,2% mit schwerem AHF wurden im Alter von 6 Jahren oder jünger eingeschult. 45,7% der Schulabsolventen beendeten ihre Schullaufbahn mit dem Erwerb des Abiturs. Schullaufbahnen variierten zwischen den verschiedenen AHF-Untergruppen. In der Auswertung aller graduierten Teilnehmer erreichten 57,3% der Patienten mit einem leichten, 47,3% mit moderatem, und 35,1% mit schwerem AHF das Abitur. Patienten mit AHF litten vermehrt an psychischen Störungen (33,3%) und mussten häufig das Schuljahr wiederholen (11,2%). Hierbei traten psychische Störungen mit der höchsten Inzidenz bei Patienten mit einem schweren angeborenen Herzfehler auf. Diese Patientengruppe mussten am häufigsten ein Schuljahr wiederholen.

Schlussfolgerung: In unserer Studie hatte die Mehrheit der teilnehmenden Patienten mit einem AHF eine normale Schulkarriere. Diese Ergebnisse sind für betroffene Familien und Ärzte von großer Bedeutung, da sie die Ängste der Eltern lindern können, indem sie zeigen, dass eine normale Schulkarriere auch mit der Diagnose eines angeborenen Herzfehlers möglich ist. Dennoch unterschieden sich das Alter und die Schulform bei der Einschulung sowie der erreichte Schulabschluss je nach Schweregrad des zugrundeliegenden angeborenen Herzfehlers. Patienten mit schweren AHF wurden häufiger mit einer psychischen Störung diagnostiziert und mussten häufiger eine Schulklasse wiederholen. Daher sind bessere Früherkennungssysteme erforderlich, um Risikopatienten zu identifizieren, die eine frühzeitige Intervention und Unterstützung benötigen.

1. Introduction

1. 1. Congenital Heart Disease (CHD)

1.1.1. A Brief Overview

Congenital heart diseases (CHDs) are defined as pathological abnormalities concerning the heart's structure and/or integrity that develop intrauterinely and are per definition present at the time of the patient's birth(1). The prevalence of children born with CHDs varies in the general population with approximately 1% of live-born children suffering from a CHD depending on the study, country and region observed(2-10). Numerous meta-analyses have reported live-birth rates slightly below 10 per 1000(4, 8). The reported CHD prevalence is highest in Asia followed by Europe and then North America(4, 8). The reported low CHD prevalence rates in the African continent and in less developed countries have been attributed predominantly to a lack of high quality prevalence studies and to subpar developed healthcare systems that may fail to adequately diagnose CHDs. Therefore, the worldwide CHD prevalence is likely to be higher than currently estimated. CHDs account for approximately 28% of all major congenital abnormalities worldwide, making them a significant health problem and the most frequent congenital abnormality of a single organ(2). In Germany alone over 7000 children are born with a CHD every year and it is estimated that these numbers will continue to increase in the years to come due to improving medical care and increasing maternal age(7).

The past decades have seen a significant increase in the size of the child and adult CHD patient communities(5, 6). This increased CHD prevalence in the general population has been attributed to two major factors. The first is constantly improving and more established healthcare systems, which have led to a significant decrease in mortality, predominantly in industrialized nations with established national healthcare systems(11). The second is improved diagnostic tools, which allow for a more exact and earlier diagnosis of potential CHDs(12). As a result, CHDs that may have remained undiagnosed in the past are now being diagnosed more frequently. More specifically, it is likely that the increased prevalence of mild CHDs can be predominantly attributed to improved prenatal examinations while an increase in the severe adult community can be attributed to improved treatment options and higher survival rates(4). The reported increase in the number of adult CHD patients has been significantly greater than the increase in the number of child CHD patients. Marelli et al. observed that approximately 66% of CHD patients were adults in the year 2010(5). For the first time the adult CHD patient pool is now larger than the child pool. The number of CHD patients reaching adulthood has increased exponentially in the past decade thanks to advancing medical care, improving

surgical techniques and on-average earlier prenatal diagnosis rates(11, 13). These advancements now ensure that over 85% of patients diagnosed with a CHD at birth or in their childhood reach adulthood compared to only 20% in the 1950s(11, 13). With continuing technological and medical advancements, it is safe to assume that the number of adult CHD patients will continue to increase in steady increments and the ratio of adult-to-child patients is likely to continue to shift in favour of adult CHD patients.

The increasing prevalence of adult CHD patients has created and will continue to create new challenges concerning long-term treatment and complications. Healthcare systems around the world will be confronted with new burdens and difficulties pertaining to the long-term treatment of adult CHD patients. In light of decreased mortality rates, the success of a treatment cannot solely be based on patients' survival rates but must take into account factors that affect a patient's later quality of life (QoL). A patient's ability to lead a normal life is paramount when electing the correct form of treatment. When assessing the validity of any possible treatment, focus has begun to shift towards parameters such as age-appropriate and adequate neurological development. In particular, a patient's ability to experience a normal childhood and upbringing and to receive an adequate education is important for their healthy development. A child's upbringing and school education set the foundation for their professional careers and significantly affect their later QoL(14, 15).

1.1.2. CHD Classification and Prevalence

The prevalence of the individual CHDs varies significantly in the general population and among different ethnic and geographic populations(3, 4). In previous studies, diagnosed CHDs have been classified into groups according to their severity for better statistical analysis. This severity ranking is based on numerous influencing factors such as mortality, complexity of the treatment required and pre- and post-surgical complications. It has become standard praxis to divide CHDs into three subgroups according to their severity, classified as mild, moderate and severe(7, 9, 11, 16).

Mild CHDs are not life-threatening during infancy or childhood and rarely cause symptoms until the patient has become older. However, mild CHDs can have a cumulative negative effect on a patient's QoL if they remain undetected and untreated(17). Mild CHDs can often be treated via minimally invasive cardiac catheter procedures and do not require extensive surgical interventions. In other cases, no treatment is required and regular follow-up examinations suffice. The most common CHDs reported tend to be Ventricular Septal Defects (VSD), Atrial Septal Defects (ASD), and Patent Ductus

Arteriosus (PDA) depending on the study format and the inclusion criteria(4, 7, 8). These mild CHDs show a high spontaneous closure rate and often do not require treatment(18).

Moderate CHDs generally have a more profound negative impact on a patient's health and over a shorter time period. However, the patient's underlying CHD is rarely immediately life threatening. Usually, definitive treatment can be delayed until the patient has reached a more optimal physical condition. Severe CHDs have a grave and nearly immediate negative effect on the patient's health(19). At times severe CHDs are not compatible with a patient's survival regardless of treatment. CHDs in this subgroup tend to be life threatening and can cause severe neurological damage within an extremely short time period. As a rule, these CHDs have to be surgically corrected as soon as possible and any delay can cause a serious increase in mortality or lead to life-long complications(20).

1.1.3. Prenatal Diagnosis

In the past decades, major technological advancements and medical improvements have been made in the field of prenatal examinations and diagnosis of CHD patients. Nowadays nearly all CHDs, especially those of the more severe variety, can be diagnosed prenatally. However, recent studies have reported great variations in detection rates depending on the study format, the CHDs in question, the expertise levels of the centres recruiting, the country of origin, distance to clinic and potential maternal risk factors surrounding the pregnancy(3, 7, 21-28). Depending upon these variables 12-45% of non-syndromic congenital heart defects are diagnosed prenatally(2, 3, 7, 12, 21-29). In high-risk pregnancies prenatal diagnosis rates of up to 80% have been observed in highly specialised centres(3, 24, 26, 30). The current diagnosis rates reported in larger European studies do not match up to the technological prenatal diagnosis possibilities. However, a clear chronological trend towards continuously improving prenatal diagnosis rates has been observed, which can be attributed to improving technology, standardization of examination techniques and a higher awareness for congenital defects among patients and physicians(4, 12, 22, 26).

CHDs classified as severe, such as Single Ventricle Defects (SVD), are diagnosed prenatally far more frequently than mild or moderate CHDs(3, 29-31). Severe CHDs normally go hand in hand with greater anatomical pathologies of the heart and are therefore easier to detect intrauterinely via an ultrasound examination than smaller structural abnormalities of the heart. Besides the severity of the CHD, surrounding risk factors strongly influence the likelihood of a prenatal diagnosis. A successful prenatal diagnosis correlates with advanced maternal age, positive family history, place of residency,

diabetes, extra-cardiac defects and higher order gestation(3, 21, 27, 28). High-risk pregnancies are monitored more closely, explaining the higher rate of diagnoses. In addition, prenatal examinations of high-risk pregnancies more frequently take place in specialised clinics(28, 30).

In theory, the prenatal diagnosis of a CHD, especially that of a moderate or severe variety, should be beneficial to a patient's mortality and long-term outcome. A prenatal diagnosis eliminates the risk of a diagnostic delay, allows delivery at specialised tertiary care centres and permits adequate medical preparations and adjustments to take place to better be able to deal with any possible complications at birth(20, 32-35).

However, studies pertaining to this matter have come to contradictory results. Numerous studies reported that a prenatal diagnosis correlates with a decrease in mortality, and a decrease in acute surgical and long-term complications, especially for severe CHD patients(20, 25, 32-35). Eckersley et al. observed an 11% increase in mortality in connection with a belated postnatal diagnosis of critical CHDs(20). Among others Calderon et al. reported fewer long-term neurological impairments and developmental deficiencies and a better overall outcome in the prenatally diagnosed CHD patient cohort presumably due to adequate surgical preparations and early neonatal surgery(34, 35). Vincenti et al. observed no contrast in the one-year morbidity and mortality between prenatally and postnatally diagnosed CHDs but reported significantly less extra-cardiac complications in the prenatally diagnosed group(25).

In contrast, other studies reported higher mortality rates and no clear neurodevelopmental differences in prenatally diagnosed CHD patients despite the fact that adequate preparations were undertaken(36-38). No significant reduction of inpatient treatment duration, duration of mechanical ventilation, requirement for postoperative support, or frequency of postoperative complications in the prenatally diagnosed patient collective were reported(39, 40). Pinto et al. highlighted the additional strain on the health system caused by a prenatal diagnosis through additional treatment costs and extended duration of inpatient treatment(41).

More severe and anatomically conspicuous CHDs are more frequently prenatally diagnosed, even within the severe CHD subgroup. The challenge and the inherent selection bias of comparing prenatally and postnatally diagnosed CHDs has been observed in previous studies(22, 25, 31). An easy solution regarding this selection bias is not in sight as randomised trials would be unethical and potentially harmful for patients. The benefits of a prenatal diagnosis remain disputed as the vast majority of CHD patients diagnosed prenatally have yet to reach adulthood.

In addition to adequate preparations, a prenatal diagnosis grants expectant mothers the option of terminating the pregnancy (Termination of Pregnancy = TOP). The highest rates of TOP have been observed in the most severe CHD cases with up to 50% of pregnancies with univentricular heart physiology and a total of approx. 17% of all major CHD cases being terminated(24, 25, 37). TOPs have increased in the past decades and correlate with the increased prenatal diagnosis rates and with increased patient awareness and education(24, 25, 37). It is important to give expectant mothers this option and to save them the potential trauma of losing their child shortly after birth due to the underlying cardiac disease. During this stressful and traumatic decision-making process, the treating physician must ensure the expectant mother is in a position where she can make an informed decision and must accompany her throughout this process and counsel her regardless of her final choice(42). A multidisciplinary team is needed to adequately inform and support the potential mother. To be able to give expectant mothers the option of TOP is important and a key reason for continuing to improve prenatal diagnosis rates.

1.1.4. Follow-Up Examinations

Patients with CHDs are considered an at-risk group for long-term complications such as developmental delays, neurodevelopmental deficiencies, psychological disorders and for problems relating to the cardiovascular system(16, 35, 38, 43). Due to the high risk for the aforementioned long-term complications the American Heart Association and the American Academy of Paediatrics have issued a joint statement emphasizing the importance of follow-up examinations in regular intervals(16). These guidelines recommend a systematic screening with regular neuropsychological assessments throughout a patient's childhood and adolescence. The aim is to analyse the patient's longitudinal development across various domains such as speech, fine and gross motor skills, coordination, communication and behaviour. Longitudinal analyses have been deemed necessary to detect subtle, possibly subclinical, deficiencies that may otherwise be overlooked or disregarded(16). An early detection and diagnosis of neurological deficiencies and developmental delays is necessary to enable adequate and timely interventions. These in turn can help prevent long-term complications that negatively influence a patient's quality of life in various domains(44-46). Timely interventional therapy during infancy and/or childhood is likely to have a greater positive influence than later treatment. Interventions when said disorders have become clinically manifest may no longer be able to affect the patient's development(44, 45).

When interviewed there is high support within the CHD patient community and their families for in-depth research and follow-up examinations(47). Though there is large support and a great potential benefit for CHD patients, follow-up examinations are often not realized due to various reasons. This has made a systematic surveillance and assessment of CHD patients and possible long-term complications virtually impossible. 50-75% of patients fail to attend follow-up examinations on a regular basis(48). Follow-up examinations have the highest attendance rate for a short time after interventional or surgical treatment of the underlying CHD(48). Male gender, distance to a clinic, connection to a non-university setting, and low underlying CHD severity have been identified as risk factors for not attending follow-up examinations(48).

Most patients are lost to follow-up during the transition from adolescence to adulthood(48, 49). This period entails many social and physical changes and patients begin to take over responsibility for their own healthcare. A stable and successful patient-physician relationship is essential in maintaining a connection throughout this period. Transitional educational programs aimed at recruiting and informing adolescent patients have failed to yield high participation rates(49).

CHD patients are in a special situation at the time of their follow-up examinations. CHD patients usually find themselves in a subjective state of well-being at the time of their check-ups. Treating physicians have a responsibility to convey the importance of said examinations to the patient and their guardians and must stress the benefits that the early detection of a possible disorder can have on a patient's later QoL. To varying degrees, patients are not satisfied with their treating physicians and a significant number are not or do not feel adequately informed regarding their CHD(13, 50-52). Patients, their families and treating physicians deem different aspects of patient education important(51, 53). This in turn can lead to dangerous misconceptions concerning the CHD and low follow-up examination attendance rates. Today, specialised physicians are still regarded as the most reliable source of information(51). Physicians must help to navigate the overabundance of information and misinformation that can be encountered online(51). Possible misconceptions regarding potential risk factors and disease management can have grave consequences on a patient's ability to lead a normal life and may negatively affect their QoL(13, 14, 52, 54). Especially topics regarding matters such as sexuality, pregnancy and contraception are not addressed sufficiently by treating physicians(54). Female patients may be too embarrassed to mention these subject matters of their own volition. A lack of knowledge in this area presents a potentially unnecessary risk for mother and

child(54). In extreme cases, female patients may wrongly fear that a pregnancy may cause their cardiac situation to deteriorate. This unfounded fear can prevent female CHD patients from having children, which can in turn greatly reduce their QoL(54). CHD patients are frequently overweight and this is in part due to misconceptions surrounding their ability to perform and pursue sports(49). Studies have shown the need for interdisciplinary education, which should include cardiologists, gynaecologists and paediatricians to help minimize knowledge gaps(51). CHD patients require lifelong multidisciplinary care, initially by a paediatric cardiologist and later by an adult specialist. Communication between the different specialists and shared treatment plans are important to prevent miscommunication and optimise patient care(55). Helm et al. observed employed patients to have a better understanding of their CHD, greater trust in their physician and less impairment in everyday life(56).

1.2. Neurological and Psychological Development

1.2.1. Brain Development

Studies employing cerebral Magnetic Resonance Imaging (cMRI) have shown that foetuses with a CHD have a smaller total brain volume, lower cerebral blood flow, lower brain maturity and a delayed cortical development(57-60). White matter injuries and unspecific lesions have been observed in a large percentage of children with CHDs before cardiac surgery(61-63). These findings highlight the negative impact that CHDs have on the intrauterine brain development of patients prior to treatment or surgery. Possible neurological damage received during anaesthesia and surgical treatment of the underlying CHD appear to play a less substantial role regarding neurological damages(63). Delayed brain maturation, lower total brain volume and lesions persist into adolescence and can correlate with the extent of the neurodevelopmental deficiencies and developmental delays(61, 64). Pathological and abnormal cMRIs are most pronounced in patients with more severe CHDs(64). Preoperative acidosis and hypoxia have been identified as additional independent risk factors(64). The exact causes of the lesions and the delayed brain maturation remain subject to controversial discussions. It is assumed that a combination of prenatal brain hypoxia and low cerebral perfusion prevent a physiological development of the brain.

1.2.2. Genetic Factors

The most at-risk CHD patients for developmental delays (DDs) and neurodevelopmental deficiencies (NDs) are children who suffer from known genetic syndromes. A high prevalence of specific CHDs have been associated with Down syndrome(65), Williams syndrome(66), and numerous other syndromes(67). It is difficult to differentiate between primary DDs and NDs caused by the underlying genetic disorder and secondary DDs and NDs caused by the patient's CHD. CHDs may aggravate DDs and NDs caused by the underlying genetic syndrome. No clear clinical advantage can be gained through a strict classification of NDs and DDs into primary and secondary. An increase in CHD patients suffering from genetic abnormalities has been observed in recent years(67). Over the last decade, genetic testing has become more routine in the diagnosis and treatment of severe CHDs. Previously overlooked genetic abnormalities that lacked any clinical stigmata are now being detected and becoming the focus of research projects. Carey et al. exposed a pathogenic copy number variant in over 10% of children with single ventricle lesions(68). In the past, such genetic abnormalities would have remained undetected due to the lack of stigmata and symptoms that would have qualified children for a genetic analysis.

1.2.3. Neurodevelopmental Deficiencies and Developmental Delays

Children with Congenital Heart Disease are a vulnerable group for neurodevelopmental deficiencies (NDs) and development delays (DDs) (16, 17, 35, 69-74) . These long-term complications are the most frequent but simultaneously the most severe because they can greatly restrict a patient's ability to lead a normal life. Numerous DDs and NDs spanning across different developmental domains and skills have been observed in various studies. Predominantly, these delays are of low-severity and subtle in their markedness(16, 38, 75, 76). CHD patients have been observed to be at risk for DDs and NDs in the areas of visual motor integration, visual construction and perception, fine and gross motor skills, attention, hand-eye-coordination, impulse-control, reasoning, language, social cognition, processing speed, mathematical achievements, intellect, memory and executive function when compared to the general population(17, 38, 69-81). Especially a patient's motor and coordination skills appear to be impaired at a young age (38).

Mussatto et al. reported that 75% of CHD patients were deemed at risk or delayed in cognitive, motor or language skills compared to only 16% of the general population(17). Von Rhein et al. observed significant intellectual and neuromotor deficiencies in 10-year-old CHD patients who had undergone

open-heart surgery(78). With high probability, many of these subtle deficiencies would remain undetected without the use of standardized evaluation tools and longitudinal studies(16). The impact an underlying CHD and corrective surgery have on a patient's IQ (Intelligence Quotient) score remain a controversial subject. Regardless of the study, patients' IQs tend to be in the low norm (-1SD) or lower, revealing at least a tendency for cognitive deficiencies(78, 82-85). Especially patients with more severe CHDs and genetic disorders are at risk for below average IQs(82, 83). The role a person's IQ plays in regards to their school and professional career remains unclear.

The reported frequency, severity and extent of NDs and DDs differ depending on the neurodevelopmental assessment tools employed, the patient's age at testing and the severity of the underlying CHD in question. Especially patients with additional genetic conditions have been identified as at-risk patients for NDs and DDs(17, 38, 82). It remains difficult to determine to what degree NDs and DDs are caused by the underlying CHD and to what extent the neurodevelopmental assessment is influenced by genetic comorbidities(38, 67), parenting style(71, 86, 87), socioeconomic status(73, 82, 88) or perioperative and postoperative complications(19, 80). Developmental delays appear to become more pronounced with a patient's age(16, 17, 75). It is unclear whether potential DDs and NDs worsen over time due to a cumulative effect of the underlying CHD in question or whether they are not adequately assessed in infants. Tools designed to evaluate DDs and NDs in new-borns and infants are very limited in their effectiveness(17). This can be attributed to the difficulty of verifying subtle cognitive, language and motor deficiencies in infants, who are already physiologically limited in these fields. Testing is more sensitive at an older age because the complexity of the skills children are required to perform increases exponentially. In addition, the amassed impact of the patients underlying cardiac defect, as well as the environmental factors may become more evident as time progresses(17). The extent to which patients' NDs and DDs affect their daily lives and their school careers is a topic of current research and a core part of our study.

1.2.4. Environmental Risk Factors

The severity of NDs and DDs can be attributed directly to the complexity of the patient's CHD but also to accompanying risk factors such as duration and complexity of surgery, amount of surgeries required, duration of inpatient treatment, age at time of surgery, post-operation complications and surrounding socioeconomic factors(73, 78, 80, 82, 83, 89, 90).

Over the past decades, the most significant advancements have been made in the surgical and perisurgical fields. Surgical techniques have improved so far that CHDs considered fatal decades ago can now be surgically corrected with a high likelihood of survival into adulthood(11). Against all expectations improvements in the intraoperative and perioperative field have failed to yield a significant decline in NDs and DDs(78, 81, 83). Approximately 30% of risk factors for NDs and DDs in CHD patients have been identified(91). Surgery and perisurgical complications appear to play a secondary role compared to the intrauterine development and to external factors such as socioeconomic status and parental education(61, 62, 74, 82).

Inpatient treatment duration is considered one of the most significant influenceable risk factors for NDs and DDs as well as for a lower IQ(17, 74, 82, 89). The stress of extended inpatient treatment can inhibit a child's normal development. Environmental and social factors have a vast influence on a patient's neurodevelopmental outcome. These external factors include a patient's Social Economic Status (SES)(74, 78, 82, 88), parenting(86, 87, 92), parental education(71, 88) and early interventional therapy(44-46).

According to the American Psychological Association Social Economic Status (SES) can be defined as a person's "social standing"(93) in society and is "measured as a combination of education, income and occupation(al prestige)"(93). Recent studies have determined that a family's income has the strongest positive correlation with a patient's QoL, health and neurological and psychological development(88). Patients of wealthier families have better access to healthcare, nutrition, housing, schooling and tutoring, enabling them to more easily overcome possible DDs and NDs(88). Most studies concerning the SES of CHD patients have been performed in the United States of America, where access to healthcare varies significantly according to a family's income and their ability to afford health insurance(88). Therefore, transferability to Germany, where health insurance is mandatory and accessible for impoverished families, may be limited.

Mothers and fathers of patients with CHDs are confronted with a very taxing and stressful situation(86, 87, 92). The majority of parents exhibit "extraordinary parenting"(86). The extensive and time intense treatment required by a large amount of CHD patients makes experiencing a normal childhood extremely difficult. Overbearing parenting has been described and this can have a negative effect on a patient in later life making separation and independence difficult(94).

1.2.5. Psychosocial, Behavioural and Social Disorders

Psychosocial adjustment difficulties, aggressive behaviour, attention problems, a lack of social and communication skills, reduced social competence, a lack of empathy and internalizing and externalizing problems are more frequent among CHD patients than among the general population(43, 94-99). Especially severe CHD patients frequently suffer from behavioural, psychological, emotional and social disorders(77, 94, 97). Internalizing behavioural problems include anxiety and depression whereas externalizing problems include aggression and self-restraint difficulties.

CHD patients have more difficulty understanding the complex affective mental states of their peers and can have trouble completing false-belief tasks(77). A lack of social and communication skills can make acquiring and maintaining friendships difficult and a reduced social competence can lead to the isolation of CHD patients at school (77, 83, 98). This puts them at risk for a host of additional psychological disorders. Especially CHD patients with severe underlying CHDs appear to struggle with the more complex and abstract social skills while simple social skills, such as emotion recognition, remain unaffected (77, 94). CHD patients can be at risk for long-term psychosocial maladjustment(96).

Shillingford et al. observed that a large number of CHD patients suffered from or were at risk of attention deficit hyperactivity disorder (ADHD) after cardiac surgery(97). 23% of 8- to 12-year-old CHD patients self-reported deficiencies in emotional, social and school skills(43). 18.6% of adolescent CHD patients viewed themselves as psychosocially impaired, emphasizing the need for targeted interventional therapy(43). It is impossible to predict the extent of psychosocial, behavioural and social problems based solely on the severity of the underlying CHD (43).

1.2.6. Intervention and Supportive Therapy

The early detection of subclinical DDs and NDs serves the purpose of enabling early interventional measures during infancy. There is a correlation between CHD severity and NDs and DDs(73). Therefore, patients with more severe and complex CHDs are the most likely to benefit from interventional therapy but the extent to which early interventional therapy benefits CHD patients remains unclear. CHD patients more frequently require speech and language therapy, occupational therapy, and physical therapy than their healthy peers do(74). The high amount of therapy received by CHD patients highlights the impact DDs and NDs have on their upbringing and schooling.

Randomized controlled trials performed by McCusker et al. analysed the benefits of early psychological intervention for CHD patients and their families(44, 45). Early psychological interventions reduced maternal stress and anxiety and improved feeding practices. At the same time, CHD patients were perceived as sick less often and missed fewer school days. These results highlight the positive effects of early interventional therapy for CHD patients as well as their parents. The diagnosis of a CHD is a traumatic experience for parents and possible interventional therapy should aim to easy their anxiety levels and help parents cope with the situation(86, 92). This benefits the patient-parent relationship and prevents overbearing parenting and helps patients lead autonomous lives(86, 87, 92).

1.3. CHD Patient School Careers

1.3.1. Academic Performance and Difficulties

NDs and DDs become most prominent in CHD patients around the age of school enrolment, when neurodevelopmental tests become more sensitive and specific and when the cumulative effect of the CHD becomes more apparent(17, 71). Prominent deficiencies for adolescents can be observed in the domains of memory, impulse-control, reasoning, language, social cognition, intelligence, executive function, processing speed, visual spatial skills, attention and social integration(17, 69-79). The extent to which said disorders negatively affect a child's academic performance remains strongly disputed. A below-average school career can have lifelong negative consequences on a patient's ability to pursue higher education and on their later career options. There is a lack of longitudinal studies that have observed how DDs and NDs influence patients' school careers and academic performances. The limited amount of studies that have looked into CHD patients' school careers and education levels have often come to contradictory conclusions(43, 100-103).

Swiss CHD patients were reported to experience similar school careers compared to the general population, but severe CHD patients were likely to receive academically lower ranked education compared to their mild and moderate CHD counterparts(100). Finnish CHD patients reported education levels comparable to those of the general population and higher employment rates(101). Danish males who had been operated for a Tetralogy of Fallot (TOF) had similar education levels to those of the general population, though more were unemployed or receiving social benefits(102). In Germany, CHD patients self-reported significantly higher final education levels than the general

population(104). After completing higher education CHD patients were more frequently employed in higher paying professions than the general population(104). Though CHD patients frequently suffered from attention deficit hyperactivity disorder (ADHD), teachers still rated the academic achievements of over 50% of enrolled CHD students as above or well above average(97). Other chronically ill patients have been observed to graduate with high level secondary school degrees. CHD patients reported high levels of satisfaction concerning their educational careers, which was attributed to the so-called "response-shift"(100). CHD patients may more easily be satisfied and more appreciative of objectively less due to hardships faced during childhood.

In contrast, other studies have reported negative findings regarding the school careers of CHD patients. Reduced educational achievements, poorer school performance, worse school competency, lower school functioning levels, memory and attention problems and poorer school QoL have been observed among long-term CHD survivors(43, 72, 99, 103). Academic performance and competency were reported reduced in CHD patients after cardiac surgery compared to the general population(79, 96). Especially processing speed and mathematical achievements have been observed to be significantly reduced in CHD patients compared to the population norm(79). Military aged male Turkish CHD patients were significantly less likely to attend and graduate from university, than men from the general population(90). CHD patients required additional tutoring or special education and often repeated a school grade. 17% of US-American CHD patients repeated at least one school grade and 23% enlisted in a 2-year first grade education program upon school enrolment(78, 97). Over 50% of students reported receiving remedial teaching and 13-15% were assigned to special education classrooms for additional support(78, 97, 99). These difficulties and the need for additional support emphasize the impact of DDs and NDs on a child's development and on his or her ability to enjoy a normal school career.

1.3.2. Patient Quality of Life

A high quality of life (QoL) is dependent upon numerous variables and can differ greatly between individuals who may view different things as important. However, it is undisputed that an individual's school and later professional career have a strong influence on their QoL(14, 105). Predicting the QoL of CHD patients based solely on the severity of their underlying CHD is impossible. Numerous cardiac specific QoL scores have been developed such as the cardiac specific Congenital Heart Adolescent and Teenager Questionnaire(14) or the cardiac specific module of the PedsQL (Paediatric Quality of

Life Inventory)(106). Various studies have observed lower parental and self-reported QoL scores in CHD patients(15, 43, 105, 107). Risk factors for a lower reported health-related quality of life among CHD patients were female sex, low educational levels and limited physical capabilities(105). A high percentage of CHD patients perceived themselves as psychosocially impaired and reported a low QoL(43, 79). Patients with severe underlying CHDs and more significant DDs and NDs have lower parental reported and self-reported QoL scores(15).

In contrast, other European studies have reported average to above-average satisfaction rates in matters pertaining to school education and employment(85, 100). However, this has been attributed to established health systems in developed European countries and to the aforementioned "response-shift"(100).

1.4. German School System

1.4.1. A Brief Overview

Information about the German school system can be found on the website of the Federal Statistical Office (Statistisches Bundesamt)(108) and on the website of the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)(109). Data on the matter of school attendance and educational achievements can be found in the analysis published in May 2018 "Schools a brief Overview: Edition 2018 (Schulen auf einen Blick: Ausgabe 2018)(108). The Federal Statistics Office releases this publication in regular intervals with the aim to assess changes and developments in school attendance and educational achievements.

1.4.2. German School Structure

Legislative power in the field of education resides within the individual German states due to the federal nature of the German political system. The individual federal states have developed different educational systems and school forms according to regional requirements and the different governing parties. Depending on the federal state in question, the transition from primary to secondary school is unique and the school curricula place emphasis on different subjects. Though there are regional differences in the school systems, the central government sets national requirements. School attendance is compulsory until the age of 15 and state schools have no tuition costs. Parents can send their child to a private school at their own cost. After primary school, students transition to different secondary school forms.

1.4.3. School Attendance and Enrolment

Typical school age is defined as any age between five and 20 years old. In the school year 2016/2017, approximately 67% of children and young adults (68% female vs. 66% male) of this age attended school. Nearly 100% of children between the ages of seven and fourteen were enrolled at school. School attendance declined rapidly after the age of fifteen and the end of compulsory attendance (96% of 15-year-olds, 72% of 16-year-olds, 46% of 17-year-olds, 23% of 18-year-olds, 7% of 19-year-olds, and 2% of 20-year-olds).

Parents can enrol their children into primary school starting at the age of five but only 0.3% of children in the general population were enrolled at school at this age in the 2016/2017 school year. 63.7% of children were enrolled at a school at the age of six and the remaining children were enrolled at the ages of seven, so approx. 100% of students aged seven to 14 were enrolled at school. Severely sick children or children that are deemed too disruptive can be enrolled at a later age or in very rare cases do not need to be enrolled at school as they are taught at home.

1.4.4. Primary and Secondary School Forms

In the school year 2016/2017, 34% of students attended a primary school (1st to 4th/5th grade), 49% attended secondary school level I (5th/6th to 10th grade) and 12% attended secondary school level II (grades 11th to 12th/13th grade). 4% of students attended special needs schools.

Depending on the federal state, different secondary school forms can be attended and final degrees of varying difficulty can be attained at these schools. The secondary school form attended is in most cases not decided at the parents' discretion. Primary school teachers offer a, to a degree, binding recommendation based on the child's academic abilities and grades.

The most academically challenging school form is the upper level secondary school ("Gymnasium"). Depending on the federal state, graduation takes place after 12th or 13th grade with a diploma referred to as the general university entrance qualifications or abitur (Allgemeine Hochschulreife). This secondary school diploma allows students to study at a university of their choice, granted their grade average permits admission. At polytechnical secondary schools, students graduate after 12th grade with a polytechnical secondary school diploma (Fachabitur) which allows students to study at a university of applied science.

Intermediate level secondary schools (Realschule) prepare students for more complex apprenticeships. Students gain practical experience that goes beyond state required compulsory elements. Students graduate after 10th grade with an intermediate school degree (Realschulabschluss) and can begin an apprenticeship or apply to an academically higher ranked school form.
Modern secondary schools (Hauptschule) offer practice-orientated classes that place little emphasis on foreign languages or more abstract academic principles. Students graduate after 9th grade with the modern secondary school degree (Hauptschulabschluss).
Comprehensive secondary schools are a combination of all the above listed school forms while multi-tiered secondary schools are a combination of intermediate and modern secondary schools. Academically higher ranked secondary school forms permit students to graduate with lower ranked secondary school diplomas without having to change school form. For example, a student can graduate from an upper level secondary school with an intermediate secondary school diploma after 10th grade.

Of the approx. 5.5 million students attending secondary school level I/II and special needs schools at secondary school level during the school year 2016/2017, 43.8% attended upper level secondary schools, 15.8% attended intermediate secondary schools and 7.5% attended modern secondary schools. 13.5% of students in secondary school attended a comprehensive secondary school and 9.8% attended multi-tiered secondary schools. The remaining 9.6% of students attended special needs schools, school independent orientation classes or Waldorf schools.

1.4.5. Special Needs Schools

Special needs schools aim to provide optimal support for children with physical, mental, and emotional impairments or disabilities. As an alternative, many schools have integrative classes. In these classes, children in need of assistance grow up in a normal school environment.
In the school year 2016/2017, 7% of students between 1st and 10th grade had special education requirements. 63.9% of these students attended special needs schools.

1.4.6. Sex Distribution

In the 2016/2017 school year, 51% of students were boys and 49% were girls. The slightly higher prevalence of male students was nearly identical in primary school as well as in secondary school level I. However, 53% of students that attended secondary school level II were female and only 47%

were male. Male students were more likely to attend special needs schools than female students (65% male vs. 35% female).

1.4.7. Grade Repetition

2.3% of the student population repeated a grade in the 2016/2017 school year. Male students were more likely to have to repeat a grade than their female counterparts (2.8% vs. 1.8% respectively). School year repetition was particularly high among the academically lower ranked secondary school forms.

1.4.8. Secondary School Graduation

In the school year 2016/2017, the largest percentage of students (43%) graduated from secondary school with an intermediate school diploma. 35% of students graduated with the general university entrance qualifications (abitur) and 0.1% graduated with a polytechnical secondary school degree. 16% of students graduated from a modern secondary school degree. More female students graduated with the general university entrance qualifications than male students, while more male students graduated with the modern secondary school diploma.

In the last decades, the percentage of students graduating from school with academically higher ranked secondary school degrees has increased. This is due to a restructuring of the German school system. 6% of students left secondary school without receiving a major degree. This group consisted predominantly of male students and the percentage has remained relatively stable over the past decade. In 2016/2017 52% of all school and post-secondary school graduates attained higher education entrance qualifications. 41% of all graduates received the general university admission qualifications and 11% graduated with the polytechnical school degree. A significant number of students from the general population attained these degrees at trade schools or during their apprenticeships as part of their post-secondary school degrees and did not graduate directly from secondary school with these degrees.

1.5. Study Outline

The aim of this study was to examine how CHD patients perform at school depending on the severity of the underlying diagnosis and how their school careers differ from the general population. CHD patients are an at-risk group for developmental delays, neurodevelopmental deficiencies and

psychological and behavioural problems. While numerous studies have reported on the prevalence and nature of NDs and DDs within the CHD patient community, the real life effect of a CHD on a patient's school career remains unclear and findings are controversial(90, 101-104).

This study compared age and school form at enrolment, school year repetition prevalence, secondary school form attended and final secondary school qualifications between CHD severity subgroups and to students from the general population.

We examined additional confounding factors such as prenatal diagnosis prevalence, prevalence of additional tutoring and interventional therapy, duration of inpatient treatment and behavioural and psychological disorder prevalence. An additional point of interest were changes in the CHD prenatal diagnosis rates in the twenty-year time period observed.

We aimed to test the following assumptions:

- Prenatal diagnosis rates of CHD patients have significantly improved in the last twenty years.
- Age at school enrolment differs significantly between CHD patients and the German general population as well as between CHD severity subgroups.
- Secondary school form attendance differs significantly between CHD patients and the German general population as well as between CHD severity subgroups.
- Secondary school diplomas differ significantly between CHD patients and the German general population as well as between CHD severity subgroups.
- Patients with CHD are at-risk for having to repeat a school year, for psychological, behavioural and learning disorders, and for requiring additional assistance in the form of early interventional therapy or after-school tutoring.

2. Method

2.1. Survey Outline

A cross-sectional study was conducted using an online multiple choice survey. The main focus of this study was to assess the educational development and academic achievements of CHD patients by taking a closer look at their underlying CHDs, additional risk factors, their upbringing, their school careers and their socioeconomic background. To gather this information, participants were asked to answer numerous questions concerning the patient's childhood, upbringing and school career as well as questions concerning parental education levels and employment status. Participant recruitment was performed through the database of the German National Register for Congenital Heart Disease (NRCHD).

All CHD patients born between 01.01.1992 and 01.01.2011 and registered in the NRCHD were invited to participate in our study. Invitation required the listing of contact information in the database of the NRCHD in the form of an e-mail or postal address (22,126 patients). Parents were asked to complete the survey if their children were unable to do so due to age or health reasons. No age requirement was set and families decided independently on the person best suited to complete the questionnaire. Inclusion occurred solely based on the diagnosis of a CHD regardless of sex, CHD severity, comorbidities, genetic syndromes and time of diagnosis (pre- vs. postnatal). All patients that had passed away since registering with the NRCHD were excluded to avoid causing family members grief through contact.

The invitations contained a link with which patients or parents were able to access the online survey between the 31.07.2017 and the 03.09.2017. Patients without internet access were able to contact the NRCHD and ask for a printed version of the questionnaire. Employees of the NRCHD not directly involved in this study later transferred the information from the returned printed surveys to the online database. Researchers directly involved in the study had no access to completed surveys or to patients. The survey varied in length depending on the participant and their response behaviour, but consisted of a maximum of 42 questions (see Appendix). Participants could define themselves as one of the following three categories: patient, parent or third party. Non patient participants were required to have guardianship of the patient to complete the survey. Each participant group (patient, parent or third party) received a slightly different survey worded specifically for them. The aim was to prevent

any possible misunderstandings by phrasing each question as precisely as possible. The questions differed only in their wording and remained the same regardless of the participant group. Participants who had previously identified themselves as parents or third party guardians were asked to define their sex and specify their age. Therefore, we were able to discern which parent primarily responded in deputy of their child.

Participation was managed using pseudonymized identification numbers. This number is specific for each patient and is known only to them and/or their legal guardian. This number allows the pseudonymized identification of the patient and their medical information in the database of the NRCHD. In addition, the identification number added a level of security and permitted only the patient or legal guardians to complete the survey. No unwanted third parties were able to access the online survey, manipulate the data and create a potential bias, however unlikely this scenario.

2.2. Survey Structure

The online survey consisted predominantly of multiple choice questions of a closed format style. Participants were given the option to add an answer possibility, if they did not feel that any option adequately reflected their situation. Closed questions were chosen due to their high comparability and objectivity, which later permitted a more precise statistical analysis. By using simple closed formatted multiple choice questions, we hoped to maximize participation and comparability, while minimizing the likelihood of a selection bias.

However, the survey did not consist solely of multiple choice questions. The first question inquired about the patient's current state of cardiac well-being in the form of a six tiered Likert scale (1 = best/6 = worst). This question belongs to the standard repertoire of the NRCHD and aims to continuously assess the cardiac state of well-being of patients registered in the database over an extended period. The final question was an open format question and allowed participants to inform us of additional aspects concerning their childhood and their school careers that had not been addressed in the survey. Participants were able to offer criticism as well as suggestions for future studies. These questions are not included in the Appendix.

The online questionnaire was created using the program EFS Survey (Questback EFS Survey 2017, Berlin Germany). The NRCHD has used this program for previous online surveys and verified its functionality and quality(52, 104).

2.3. Survey Completion

The online survey could be accessed and completed by potential participants between the 31.07.2017 and the 03.09.2017. Past experiences with surveys conducted by the NRCHD have revealed that no significant additional participation can be observed after the first two months. Patients initially contacted by e-mail were reminded to participate after three weeks with an additional e-mail. Due to logistical and financial reasons, people invited to participate by mail did not receive an additional reminder. The survey could be completed over an extended period and did not need to be completed in one sitting. Between the individual sessions, the participant's progress was saved and the survey could always be continued without the need to start again or repeat any questions.

Diligent completion of the survey took between 10 to 15 minutes and no additional tools or documents were required to answer any questions. Participants were unable to skip questions and could only proceed to the next question if the previous question had been answered. Participants could respond with "I don't know" if they did not wish to answer a question. To reduce the likelihood of a selection bias no participation incentives or rewards were offered. Participants received no remuneration for the time spent completing the questionnaire. Our patient pool consisted of a very diverse age and socioeconomic group. By not providing an incentive, we hoped to prevent the overrepresentation of certain subgroups. In addition, as a rule the NRCHD does not offer any incentives for participation recruitment for studies conducted under its patronage.

2.4. Participation Consent

Completing and submitting the online survey constituted participation consent. Before participants could begin with the survey and enter their pseudonymized identification number, an information page outlined the motivation behind our survey. Patients were given an overview of what kind of questions to expect and the information we hoped to collect.

Completing every question of the survey required repeated affirmative action on the part of the participant and could not occur by accident. As mentioned above, patients registered in the NRCHD have a randomized number that is generated upon registration. The number was used to later identify

the questionnaires anonymously and to pseudonymize the data. The data obtained from these questionnaires is stored separately from any person-identifying data. All statistical analyses were carried out without any patient related knowledge and solely using the pseudonymized surveys and medical data stored in the NRCHD. Only employees of the NRCHD not directly involved in this study had access to patient-identifying data.

2.5. The German National Register for Congenital Heart Disease

The German National Register for Congenital Heart Disease (German: Deutsches Register für angeborene Herzfehler) is the core project of the Competence Network for Congenital Heart Disease. The NRCHD is the main database for medical information on CHD patients in Germany. The database is continuously updated and maintained with the use of current physician's reports, sent to the NRCHD by the institutes in charge of the patient`s treatment. The Competence Network receives funding from both the Federal Ministry of Education and Research and the German Centre for Cardiovascular Research, but is an entity that operates independently of both these institutions (https://www.kompetenznetz-ahf.de/).

Registration in the NRCHD takes place on a voluntary basis. When a patient with a congenital heart disease is still a minor, their parents are given the opportunity to enrol in the NRCHD. In return enrolled patients are able to take part in studies organized and funded by the NRCHD and receive regular updates regarding the current state of research and news of medical advancements. Upon reaching adulthood (18 years of age), the NRCHD inquires as to whether the patient would like to remain enrolled. Independent parent and patient platforms advocate enrolment using various mediums including websites, online forums and print. The specialized physician in charge of treatment should offer enrolment to all patients suffering from a CHD without any exceptions. It is difficult to oversee this process and it is unclear whether parents are given the opportunity to register their child regardless of CHD severity or whether physicians offer enrolment to a preselected group of patients with more severe CHDs. Additionally, there are no statistical analyses as to how many patients/families decline initial enrolment and for what reasons. Studies assessing the accuracy of the NRCHD patient pool have come to the conclusion that possible biases at enrolment do not lead to any major distortions(10). The population of CHD patients in the NRCHD database is similar to that of large prevalence studies such as the Linde et al. meta-analysis(8, 10). The representativeness of the National Register has been

analysed and the prevalence rates of the various CHDs are accurate(10). A slight overrepresentation of severe CHDs in the National Register has been reported, but these prevalence deviations remain within an acceptable range and can be attributed to the fact that the NRCHD is a clinical registry, making it more likely for patients with clinically apparent CHDs to enrol(10). Consisting of 52,582 members (as of May 2017), the NRCHD is Europe's largest registry for CHD patients.

2.6. The Questionnaire

The survey consisted of a maximum of 42 questions. From a participant's point of view the survey was not divided into subsections. After completing a question, the participant was forwarded directly to the next question. However, the survey can be divided into eight different sections based on the topics addressed. Sections one to seven collected data on the patient and were in a rough chronical order starting with the patient's birth and ending with their post school careers. The eighth section collected information concerning the patient's parents and aimed to assess the patient's socioeconomic background.

2.6.1. Section I: Personal Data

After accessing the link, potential participants were initially asked to use their pseudonymized identification number to register and log in to the survey. The participants identified themselves as either patients, parents or third party guardians. The latter were asked to clarify their relationship to the patient (e.g. relative, foster parent, etc.). Parents and third party participants received two additional questions to determine their sex and age.

The patient's sex and age were determined and the patient's current cardiac state of well-being was reported using a six-tiered Likert scale (1=very good/6=very bad).

2.6.2. Section II: Pregnancy and Birth

Participants reported on the circumstances surrounding the pregnancy of the patient's mother, the time of diagnosis (prenatal vs. postnatal), the form of birth (vaginal vs. caesarean) and the gestational age at birth. The aim was to collect data regarding possible risk and protective factors that may have influenced CHD patients' later school careers and academic performances.

2.6.3. Section III: CHD Diagnosis

Participants reported the exact nature and severity of the patient's CHD as well as the existence of any underlying genetic syndromes and/or comorbidities. The aim was to collect data about the presence of any additional independent risk factors that may have had a negative impact on a patient's school career, so that these could later be ruled out as confounding factors. We were able to compare the patient's stated diagnosis with the medical information in our database. For later statistical analysis, the medical information in the NRCHD database was used in order to prevent a reporting bias.

Data on possible diagnoses of psychological, behavioural or learning disorders by a medical professional (psychiatrist/psychologist) was gathered to be later ruled out as a possible confounding factor and to examine the correlation between certain disorders and CHD severity. Psychological disorders included but were not limited to depression, schizophrenia and anxiety disorders.

2.6.4. Section IV: Infancy

In this section information concerning the patient's early childhood and upbringing was collected. Of special interest were factors such as total inpatient treatment duration prior to school enrolment, breastfeeding habits and vaccination records.

2.6.5. Section V: Upbringing

Participants answered questions regarding the patients' families and their upbringing. Information regarding siblings' cardiac well-being and school careers was ascertained. The patient's main caregiver (e.g. mother/father/relatives) during childhood and school was determined. In addition, participants reported whether the patient had received early interventional therapies (e.g. physiotherapy/speech therapy/etc.) for a minimum of three months.

2.6.6. Section VI: School Careers

Questions concerning patients' school careers and academic achievements comprised the core of our survey. Information regarding the patient's age and school form at enrolment was gathered. Participants reported on the patient's academic achievements, the secondary school form attended and on the final secondary school degree obtained. The primary aim of our study was to determine whether CHD patients experienced school careers comparable to the general population. Questions were

formulated in a manner so that the information would be easier to compare to data released from the Federal German Statistics Office: “Schulen auf einen Blick: 2018”(108). Numerous aspects in which a CHD patient’s school experiences might have differed were examined more closely, such as the amount of additional tutoring received or their ability to participate in physical education classes.

2.6.7. Section VII: Post School Careers

Participants reported on patient’s experiences and careers after graduating from secondary school. Of interest was whether patients had sought higher education at a university or whether they had begun an internship or a vocational training.

Participants were able to give multiple answers if patients had undertaken numerous different activities after secondary school graduation. For example, if a patient had travelled abroad before starting to study he was able to list both activities.

2.6.8. Section VIII: Social Economic Status

Questions from this section aimed to clarify the social economic status (SES) of the parents to determine the impact these factors may have had on a patient’s academic success. This section consisted of three questions concerning the patient’s father’s academic and professional career and three identical questions directed at the patient’s mother. Their level of education and qualifications were determined as well as their professional standing. We deemed a question concerning the exact income of the patient’s parents as too invasive and feared it may lead to a reporting bias. In addition, income amount is liable to fluctuations over extended periods of time and therefore no reliable parameter.

2.7. CHD Classification

The cardiac diagnoses were arranged in accordance with the classification of the international Pediatric and Congenital Cardiac Code (IPCC code)(110). For further statistical analysis, the individual CHD diagnoses were organized into four groups, loosely based on a modified classification system previously used by Schwedler et al.(7) and Pfitzer et al.(104).

Table 1

CHD Severity Classification

CHDs were divided into four subgroups according to their severity. Our classification system was loosely based on classification systems previously used by Schwedler et al.(7) and Pfitzer et al.(104).

CHD Severity	**CHD Diagnosis**
Mild CHD	Ventricular Septal Defects (VSD) Atrial Septal Defects (ASD) Patent Arterial Duct (PAD) Pulmonary Valve Disease and Anomalies Tricuspid Valve Anomalies Patent Foramen Ovale Minor Aortic Valve Diseases
Moderate CHD	Atrioventricular Septal Defect (AVSD) Aortic Valve Disease Coarctation of the Aorta (CoA) Partial Anomalous Pulmonary Venous Connection (PAPVC) Fistula of the Coronary Arteries Major Ventricular Septal Defects Shone Syndrome
Severe CHD	All Univentricular Heart Defects Tetralogy of Fallot (TOF) Pulmonary Atresia (PA) Double Outlet Right Ventricle (DORV) Transposition of the Great Arteries (TGA) Common Artery Trunk (CAT) Interrupted Aortic Arch (IAA) Total Anomalous Pulmonary Venous Connection (TAPVC) Anomaly of the Coronary Arteries Ebstein's Malformation
Unclassified CHD	Cardiomyopathy (CMP) Marfan Syndrome Atrioventricular Block III Cardiac Arrhythmias Wolf-Parkinson-White Syndrome Brugada Syndrome Other Anomalies of the Electrical Conduction System Tumours of the Heart

CHD prevalence distribution was analysed using the patient's medical information from the NRCHD database. This information is continuously updated using the latest medical reports sent to the NRCHD from the treating medical facility, provided the patient has given consent. Medical data provided by treating facilities and not self-reported diagnoses were used to prevent a reporting bias

from the patients, who may not be aware of the exact nature of their CHD. Patients suffering from numerous different CHDs were only analysed with regards to their most severe CHD. Suffering from numerous CHDs did not influence severity classification as only the patient's most severe CHD was used for further analysis. The possible cumulative effect of multiple low severity CHDs was not taken into consideration.

2.8. Data Protection and Privacy Policy

All data is stored as part of the data protection concept of the NRCHD, which is registered with the Berlin Commissioner for Data Protection and Information Freedom (No. 531.390). Only employees of the NRCHD not directly involved in this study had access to person identifying data. Researchers only received pseudonymized data for statistical analyses. No person identifying data was used and no patients were directly referenced in this study. The anonymization of data protects the identities of all participants and simultaneously prevents possible biases. The ethical review board of the Charité – University Medicine Berlin has approved all research conducted within the scope of the registry. In addition, the ethical review board of the Charité – University Medicine Berlin granted specific approval for this survey (No.EA2/137/17).

2.9. Statistical Analysis

Different samples were created for further statistical analysis of the individual subgroups. For example, when analysing patients' secondary school careers, all patients not yet enrolled in secondary school were excluded. All statistical analyses performed were descriptive and were performed using SPSS (Statistics for Windows, Version 25.0, IBM Corp. Armonk, NY). In later severity subgroup comparisons, the unclassified severity population was not analysed due to its small size and limited comparability. During analyses of the entire CHD patient population the unclassified severity population was included. At times responses were grouped into categorical answers to allow for a better analysis of certain questions. The manner in which responses were grouped is explained at each point in the results section. Statistical differences between groups were determined with the chi-square test.

The comparability of our data and the census data was limited due to the nature of the data collected and the time period observed(108). Therefore, a statistical analysis between the data sets was not

performed. The census data contains information regarding the 2016/2017 school year, while our data spans a period of 20 years. All conclusions and results are of an indicative nature and show general trends.

3. Results

3.1. Final Participation

22,126 patients and their families were contacted and asked to participate in our survey. Possible participants were contacted via e-mail (5,321) or via postal services (16,805) using the contact information stored in the NRCHD database. An approximately equal number of female (10,715/ 49.5%) and male (11,411/ 51.5%) patients and their families were initially asked to participate in our survey. The number of participants who actually received a participation invitation could not be assessed, as there was no way to verify whether the patient's contact details were still up to date.

Figure 1

Study Participation

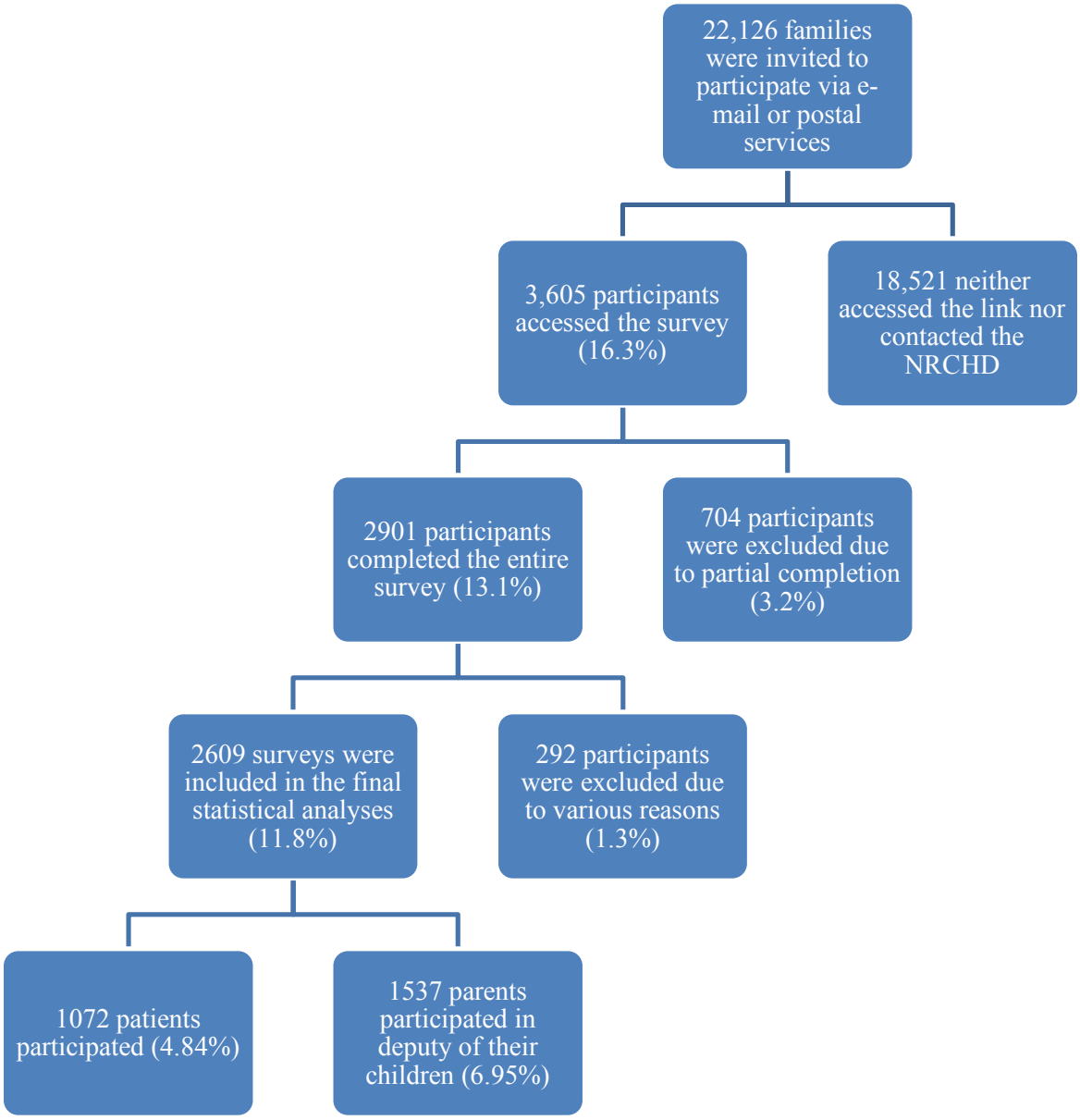

Figure 1: Survey participation after exclusion of participants for incomplete surveys and not up to date medical histories. The number of final participants originally invited by either post or email was not assessed due to data protection restrictions.

3,605 (16.3%) patients or their parents accessed the online survey using the link provided per e-mail or per post. In these cases, we can be certain that the contact information stored in the NRCHD database was up to date. Of the 3,605 individuals that accessed the survey, 2,901 (80.5%) participants

completed the entire questionnaire and were thereby eligible for inclusion into our study cohort. Detailed information regarding the underlying CHD diagnosis as well as clinical data from medical records were available for 2,609 (72.4%) patients. 292 patients (8.1%) had to be excluded primarily due to a lack of current medical information in the NRCHD database. This is the case when patients register but clinics fail to send up to date medical reports to the NRCHD. The surveys of 2,609 (11.8%) patients and parents form the basis of our statistical analysis (Figure 1). Due to data protection guidelines we were unable to analyse how many of the included patients were originally invited by email or by post.

Figure 2

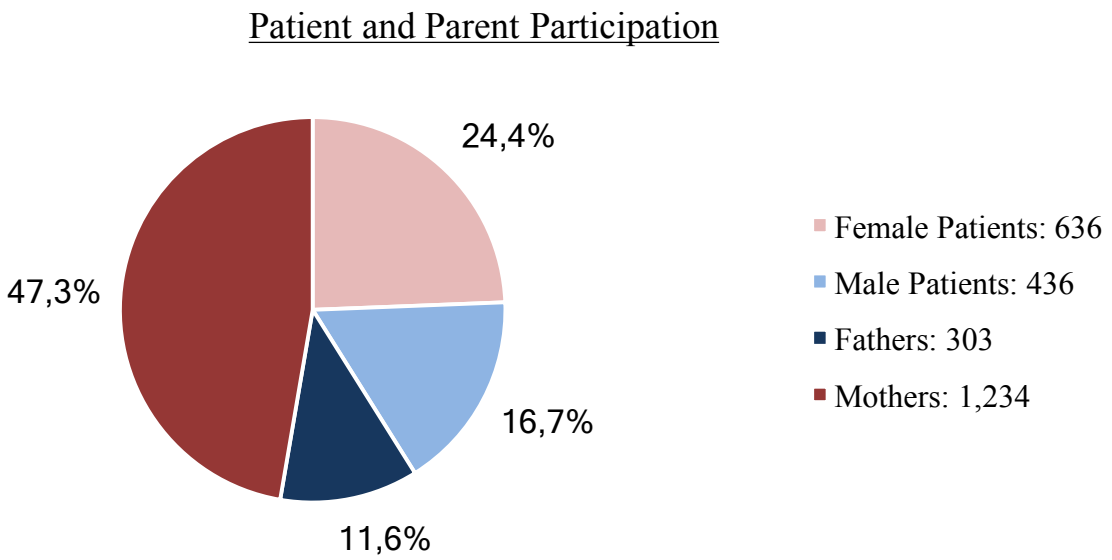

Figure 2: Distribution of the four different participant groups in our study: female patients, male patients, fathers, and mothers. No participants identified themselves as third party individuals.

Of the 2,609 surveys analysed in our study 1,072 (41.1%) were completed by patients (mean age 18.2 ± 4.4 years, female = 636 (59.3%)) and 1,537 (58.9%) were completed by parents (mean age 44.1 ± 6.1 years, female = 1,234 (80.3%)) who completed the questionnaire in deputy of their children. No participants identified themselves as third party legal guardians.

Figure 3

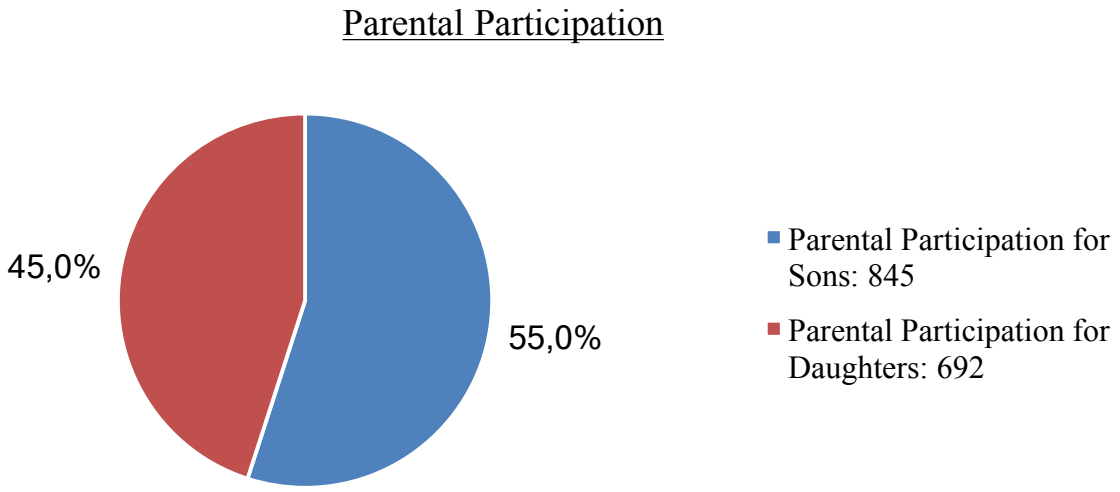

Figure 3: Parents were able to complete the survey in deputy of their children. Parental participation differed depending on the sex of the child in question.

A greater number of female patients (58.9%) and mothers (80.3%) participated in the study compared to their male counterparts. Of the total 2,609 participants, 1,870 (71.7%) were female and 739 (28.3%) were male. 845 parents (55%) completed the survey in deputy of their sons, and 692 (45%) parents in deputy of their daughters (Figure 3). Parents were more likely to answer in deputy of their sons than in deputy of their daughters.

Figure 4

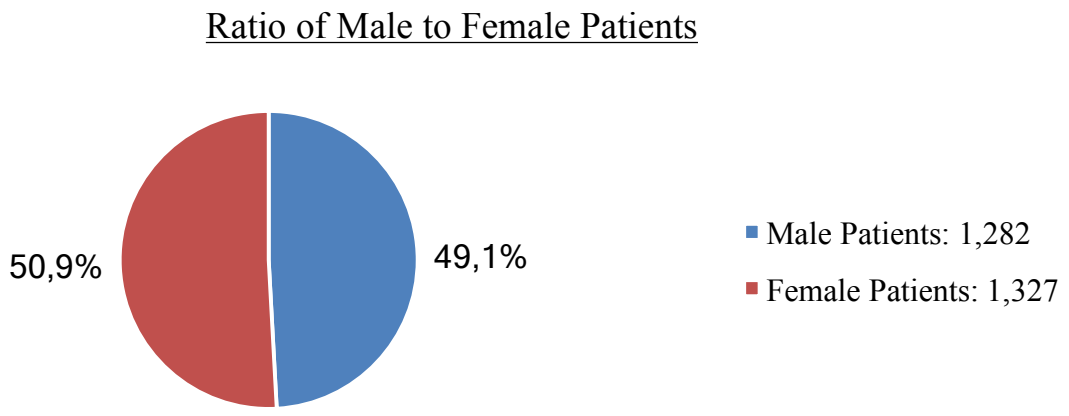

Figure 4: Final CHD patient sex distribution. The final sex distribution was approximately equal.

1,327 female (50.9%) and 1,282 male (49.1%) patients were included in our study after exclusion. More female patients participated, but more parents completed the questionnaire in deputy of their sons explaining the approximately equal final number of female and male patients included in our study. The mean age of female (20.2 years of age) and male (20.4 years of age) patient participants did not differ significantly.

3.2. CHD Distribution

CHD prevalence distribution was analysed using the patient's medical information from the NRCHD database. CHDs were assigned to a severity subgroup according to our classification system (Table 1).

Figure 5

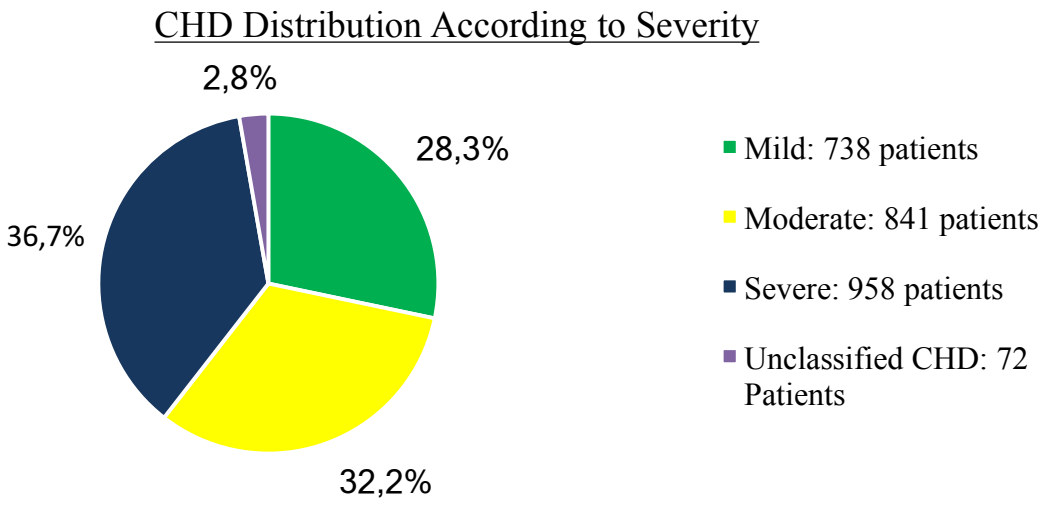

Figure 5: CHD distribution of patients according to severity. According to our classification system, CHDs were organized into the following categories: mild, moderate, severe or unclassified (see Table 1).

Prevalence of the individual severity subgroups was as follows: mild CHD patients: 738 (28.3%); moderate CHD patients: 841 (32.2%); severe CHD patients: 958 patients (36.7%) and unclassified CHD patients: 72 patients (2.8%). Severe CHD patients and their families participated more often and subsequently the severe CHD patient subpopulation was the largest included in our study (Figure 5).

Figure 6

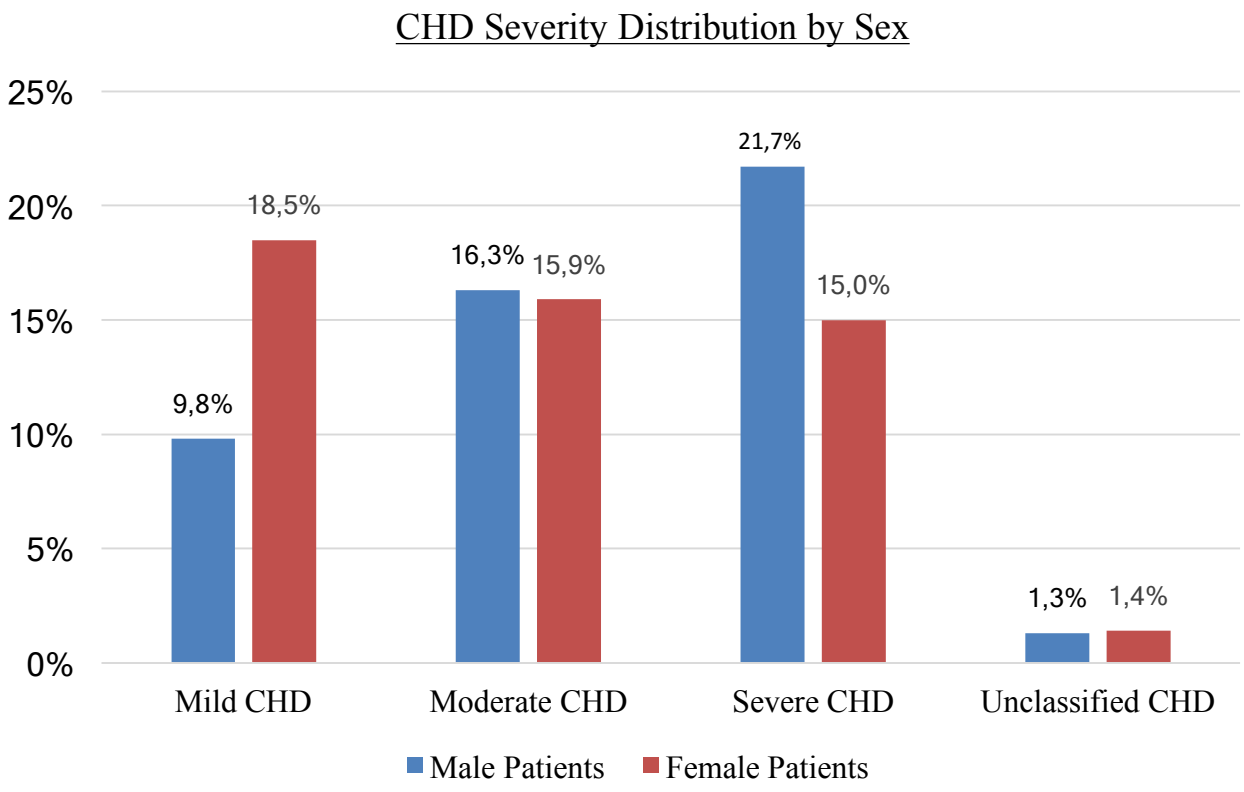

Figure 6: CHD severity distribution according to patient sex.

Prevalence of the individual severity subgroups varied depending on a patient's sex. Significant differences in female and male participation rates were observed in the mild ($p < 0.001$) and severe ($p < 0.001$) CHD subpopulations but not in the moderate CHD patient group. Significantly more female (482 patients; 18.5%) than male mild CHD patients (256 patients; 9.8%) but significantly more male (566 patients; 21.7%) than female severe CHD patients (392 patients; 15%) participated. There was no significant sex difference among the moderate CHD subpopulation.

Table 2

CHD Distribution

Medical information within the NRCHD database was used to identify the individual CHDs. Self-reported diagnoses were not used to prevent a possible reporting bias; n = sample size. The chi-square test was used for nominal variables. n.s. = not significant. Statistical significance when $p < 0.05$. When analysing statistical differences of the individual CHDs, the CHD in question was tested against all other CHDs grouped. The "Others" group consisted of: Cardiomyopathy, Tricuspid Atresia, Total Anomalous Pulmonary Venous Connection, Ebstein's Malformation, Complex Transposition of Great Arteries, Congenitally Corrected Transposition of the Great Arteries, Interruption of the Aortic Arch, Anomaly of the Coronary Arteries, Pulmonary Artery Anomaly, Patent Foramen Ovale, Partial Anomalous Pulmonary Venous Connection, Marfan syndrome, Anomalies of the Electrical Conduction System, Brugada Syndrome, Wolf-Parkinson-White Syndrome, Heart Tumours, AV-Block III, Cardiac Arrhythmia and Shone syndrome.

	Total Sample	**Male patients**	**Female patients**	**p-value: male vs. female**
	(n = 2,609)	*(n = 1,282)*	*(n = 1,327)*	
Ventricle Septal Defect (VSD)	535 (20.5%)	224 (17.5%)	311 (23.4%)	$p < 0.001$
Univentricular Heart Defect (UVH)	304 (11.7%)	198 (15.4%)	106 (8%)	$p < 0.001$
Tetralogy of Fallot (TOF)	289 (11.1%)	156 (12.2%)	133 (10%)	n.s.
Atrial Septal Defect (ASD)	268 (10.3%)	75 (5.9%)	193 (14.5%)	$p < 0.001$
Coarctation of the Aorta (CoA)	196 (7.5%)	104 (8.1%)	92 (6.9%)	n.s.
Aortic Valve Disease (AoV)	179 (6.9%)	117 (9.1%)	62 (4.7%)	$p < 0.001$
Transposition of the Great Arteries (TGA)	174 (6.7%)	116 (9%)	58 (4.4%)	$p < 0.001$
Atrioventricular Septal Defect (AVSD)	125 (4.8%)	63 (4.9%)	62 (4.7%)	n.s.
Pulmonary Valve Disease (PaV)	110 (4.2%)	43 (3.4%)	67 (5%)	$p < 0.05$
Patent Arterial Duct (PAD)	62 (2.4%)	15 (1.2%)	47 (3.5%)	$p < 0.001$
Others	367 (13.9%)	171 (2.1%)	196 (3.6%)	--

The ventricular septal defect (VSD) (535 patients, 20.5%) was the most common CHD within our patient cohort followed by univentricular heart defects (UVH) (304 patients, 11.7%), Tetralogy of Fallot (TOF) (289 patients, 11%) and atrial septal defects (ASD) (268 patients, 10.3%). These four CHDs combined accounted for 53.5% (1,396 patients) of the CHDs in our study. The second and third most common CHDs were classified as severe CHDs with 593 (22.8%) patients suffering from either a UVH or a TOF (see table 2).

Between both sexes there were significant differences in the prevalence of the individual CHDs ($p < 0.001$). For example, UVHs were significantly more common in the male CHD patient population (15.4% vs. 8%; $p < 0.001$), while ASDs and VSDs were significantly more frequent in female CHD patients (14.5% vs. 5.9%; $p < 0.001$/ 23.4% vs. 17.5%; $p < 0.001$).

3.3. Prenatal Diagnosis Rates

The self-reported prenatal diagnosis rates of CHD patients were analysed between the years 1992 and 2011. Of special interest was to what degree self-reported prenatal diagnosis rates between parents and patients differed and whether prenatal diagnosis rates had improved over time.

Table 3

Prenatal CHD Diagnosis Rates

All self-reported prenatal CHD diagnosis rates. Self-reported prenatal diagnosis rates were compared between patient and parent participants. n = sample size. Statistical significance when $p < 0.05$. The chi-square test was used for nominal variables. During the statistical analysis of the response in question, the remaining responses were grouped and tested against.

	Total Sample	**Patients**	**Parents**	**p-value: Patient vs. Parent**
	(n = 2,609)	*(n = 1,072)*	*(n = 1,537)*	
Prenatal Diagnosis	451 (17.3%)	119 (11.1%)	332 (21.6%)	$p < 0.001$
Postnatal Diagnosis	2,079 (79.7%)	883 (82.4%)	1,196 (77.8%)	$p < 0.005$
I Don't Know (IDK)	79 (3%)	70 (6.5%)	9 (0.6%)	$p < 0.001$

17.3% of participants (451 participants) reported the occurrence of a prenatal diagnosis, while 79.7% (2,079 participants) reported a postnatal diagnosis of the CHD. The remaining 3% (79 participants) no longer remembered the exact time of diagnosis. Self-reported prenatal diagnosis rates differed significantly between the patient and the parent subgroups. 332 parents (21.6%) but only 119 patients

(11.1%) reported the occurrence of a prenatal diagnosis. When asked about the time of diagnosis of the underlying CHD, patients (70 patients, 6.5%) more frequently answered with "I Don't Know" than their parents (9 parents, 0.6%) (Table 3).

For the following analysis, the responses "Postnatal Diagnosis" and "IDK" from Table 3 were grouped and tested against "Prenatal Diagnosis". Parents reported the occurrence of a prenatal diagnosis significantly more often than CHD patients did ($p < 0.001$). To compare how well patients and parents remembered the prenatal examinations the responses "Prenatal CHD Diagnosis" and "Postnatal CHD Diagnosis" from Table 3 were grouped and tested against "IDK". Patients were significantly more likely to have forgotten the exact time of diagnosis than their parents (6.5% vs. 0.6%, $p < 0.001$).

Table 4

Prenatal diagnosis rates depending on severity

All self-reported prenatal CHD diagnosis rates. No differentiation was made between parent and patient participants; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 2,609)	*(n = 738)*	*(n = 841)*	*(n = 958)*	*(n = 72)*
Prenatal Diagnosis	451 (17.3%)	59 (7.9%)	114 (13.6%)	265 (27.7%)	13 (18%)
Postnatal Diagnosis	2,079 (79.7%)	653 (88.5%)	698 (83%)	675 (70.5%)	53 (73.6%)
I Don't Know (IDK)	79 (3%)	26 (3.5%)	29 (3.4%)	18 (1.9%)	6 (8.3%)

Prenatal detection rates were strongly influenced by the severity of the underlying CHD in question. 7.9% (59 patients) of all mild (738 patients), 13.6% (114 patients) of all moderate (841 patients) and 27.7% (265 patients) of all severe CHDs (958 patients) were prenatally diagnosed. For the following analysis, the responses "Postnatal Diagnosis" and "IDK" from Table 4 were grouped and tested against the response "Prenatal Diagnosis". Severe CHDs were diagnosed prenatally significantly more often than mild ($p < 0.001$) or moderate CHDs ($p < 0.001$) and moderate CHDs were diagnosed prenatally significantly more often than mild CHDs were ($p < 0.001$).

In addition, participants were more likely to answer the question regarding time of diagnosis with "I Don't Know" if the CHD in question was less severe. Participants reported to be unsure of the time of diagnosis in 3.5% of mild (26 patients) and 3.4% of moderate (29 patients) but only in 1.9% (18 patients) of severe CHDs.

To analyse how CHD severity influenced participants' memories the responses "Prenatal Diagnosis" and "Postnatal Diagnosis" were grouped and tested against "IDK" from Table 4. A significant difference was reported between the mild and severe ($p < 0.05$) and the moderate and severe ($p < 0.05$) severity subgroups.

451 participants reported the prenatal diagnosis of the CHD in question. More than half (265 patients, 58.6%) of all prenatally diagnosed CHDs were classified as severe, highlighting the influence of severity on the time of diagnosis.

Table 5

Prenatal Diagnosis Variation analysed in 5-year intervals

Analysis of prenatal diagnosis rates in five-year intervals from 1992 until 2011 independent of CHD severity and participant group; n = sample size.

	1992-1996	**1997-2001**	**2002-2006**	**2007-2011**
	(n = 465)	*(n = 621)*	*(n = 707)*	*(n = 816)*
Prenatal Diagnosis	32 (6.9%)	74 (11.9%)	131 (18.5%)	214 (26.2%)
Postnatal Diagnosis	401 (86.2%)	516 (83.1%)	564 (79.8%)	598 (73.3%)
I Don't Know (IDK)	32 (6.9%)	31 (5%)	12 (1.7%)	4 (0.5%)

In the years analysed between 1992 and 2011, prenatal CHD detection rates improved in steady increments. For a better statistical analysis, the time period observed was divided into five-year intervals. Prenatal detection rates improved between each interval (Table 5). A CHD was more than three times as likely to be prenatally diagnosed between 2007 and 2011 than between 1992 and 1996 (6.9% vs. 26.2%) (Table 5).

For the following analysis, the responses "Postnatal Diagnosis" and "IDK" from Table 5 were grouped and tested against "Prenatal Diagnosis". A significant increase in the prenatal diagnosis rates was observed between each 5-year interval examined (1992-1996 vs. 1997-2001: $p < 0.01$; 1997-2001 vs. 2002-2006: $p < 0.005$; 2002-2006 vs. 2007-2011: $p < 0.001$). The difference was not significant in all severity subgroups between each five-year interval.

While the likelihood of a prenatal diagnosis increased between each five-year interval, participants also had a greater difficulty remembering exactly when the diagnosis took place the further it lay in

the past. To analyse participants' memories regarding a diagnosis the responses "Prenatal Diagnosis" and "Postnatal Diagnosis" were grouped and tested against "IDK". A significant difference was observed between the following 5-year intervals: 1997-2001 vs. 2002-2006: $p < 0.005$; 2002-2006 vs. 2007-2011: $p < 0.05$. The further the event lay in the past, the more likely participants were to forget when exactly the CHD had been diagnosed.

Table 6

Secondary School Degree depending on the Time of Diagnosis

Analysis of the influence of a prenatal diagnosis on secondary school graduation; n = sample size. No significant differences were observed using the chi-square test. Only patients that had completed secondary school were analysed.

	Prenatal Diagnosis	**Postnatal Diagnosis**	**I Don't Know**
	(n = 69)	*(n = 703)*	*(n = 47)*
Left Secondary School without Graduating	3 (4.3%)	22 (3.1%)	0 (0.0%)
Modern Secondary School Degree	2 (2.9%)	64 (9.1%)	2 (4.3%)
Intermediate Secondary School Degree	18 (26.1%)	159 (22.6%)	12 (25.5%)
Polytechnical Secondary School Degree	8 (11.6%)	89 (12.7%)	4 (8.5%)
Upper Level Secondary School Degree	33 (47.8%)	313 (44.5%)	28 (59.6%)
Other	5 (7.2%)	55 (7.8%)	1 (2.1%)
I Don't Know (IDK)	0 (0.0%)	1 (0.1)	0 (0.0%)

The occurrence of a prenatal CHD diagnosis did not have a significant influence on a CHD patient's school career. Neither the secondary school attended nor the final degree upon graduation appear to have been significantly influenced by the occurrence of a prenatal diagnosis (Table 6).

3.4. Early Supportive Therapy

Table 7

Early Supportive Therapy of CHD Patients

Early supportive therapy received according to CHD severity; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 2,609)	*(n = 738)*	*(n = 841)*	*(n = 958)*	*(n = 72)*
Yes	1,336 (51.2%)	297 (40.2%)	416 (49.5%)	600 (62.6%)	23 (31.9%)
No	1,232 (47.2%)	431 (58.4%)	409 (48.6%)	343 (35.8%)	49 (68.1%)
I Don't Know (IDK)	41 (1.6%)	10 (1.4%)	16 (1.9%)	15 (1.6%)	-

1,336 (51.2%) CHD participants reported that the patient received some form of early interventional treatment prior to school enrolment for a period of at least 3 months. Interventional treatment measures were defined as but not limited to, occupational, physical or speech therapy. The reasons behind receiving early supportive treatment were not ascertained. Large differences between the sexes and the individual severity subgroups were observed.

For the following analyses, the responses "No" and "IDK" from Table 6 were grouped and tested against "Yes". Significantly more male (770 patients; 60.1%) than female (566 patients; 42.7%; $p < 0.001$) CHD patients received early interventional therapy. A significant sex difference was observed in all severity subgroups: mild ($p < 0.001$); moderate ($p < 0.001$); severe ($p < 0.005$).

297 (40.2%) mild, 416 (49.5%) moderate and 600 (62.2%) severe CHD patients received some form of early supportive therapy. Significant differences in the rates at which CHD patients received early interventional therapy were observed between the following severity subgroups: mild vs. moderate ($p < 0.005$), mild vs. severe ($p < 0.001$) and moderate vs. severe ($p < 0.001$). Severe CHD patients received significantly more early interventional therapy than mild or moderate CHD patients and moderate received significantly more than mild CHD patients. A significant difference in early interventional therapy according to severity was observed within both the female ($p < 0.001$) and male ($p < 0.001$) CHD patient subgroups.

3.5. Age and School Form at Enrolment

Table 8

School Form at Enrolment

School form at enrolment depending on CHD severity. Patients not yet enrolled reported the school form they would soon attend or "I Don't Know" if they had not yet decided on which school form to attend; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 2,609)	*(n = 738)*	*(n = 841)*	*(n = 958)*	*(n = 72)*
Elementary School	2177 (83.4%)	682 (92.4%)	680 (80.9%)	749 (78.2%)	66 (91.7%)
Elementary School in an Integration Class	104 (4%)	16 (2.2%)	42 (5%)	45 (4.7%)	1 (1.4%)
Special Needs School	228 (8.7%)	24 (3.3%)	83 (9.9%)	119 (12.4%)	2 (2.8%)
Alternative School Form	90 (3.4%)	15 (2%)	33 (3.9%)	39 (4.1%)	3 (4.2%)
I Don't Know (IDK)	10 (0.4%)	1 (0.1%)	2 (0.4%)	6 (0.6%)	-

83.4% (2,177 patients) of participants reported that the CHD patient had been enrolled at a normal elementary school. 12.7% (332 patients) of patients required some form of special assistance and attended either special needs schools (8.7%; 228 patients) or integrative special needs classes at normal elementary schools (4%; 104 patients). 0.4% (10 patients) of participants no longer remembered or had not yet decided which school form to enrol in and answered with "I Don't Know". Patients not yet attending school stated which school form they would enrol in the following year (Table 8).

Initial school form at enrolment differed significantly between female and male CHD patients ($p < 0.005$). 80.5% (1032 patients) of male CHD patients enrolled at a normal elementary school in contrast to 86.3% (1145 patients) of female CHD patients, while 15% (193) of male CHD patients (4.4% integrative class; 10.6% special needs school) had special education needs compared to 10.4% (139) of female patients (3.5% integrative class; 6.9% special needs school). Among CHD patients with

special assistance requirements, special needs schools were attended more frequently than elementary schools with integrative classes (8.7% vs. 4%).

The school form initially enrolled in varied significantly depending on the severity of the CHD in question ($p < 0.001$). 92.4% (692) of patients with mild CHDs were enrolled at a normal elementary school. However, only 80.9% (680) of all moderate and 78.2% (749) of all severe CHD patients were able to enrol at a normal elementary school.

For the following analysis, the response "Elementary School" from Table 8 was tested against all other responses grouped. Significantly more mild CHD patients enrolled at a normal elementary school than moderate (92.4% vs. 80.9%, $p < 0.001$) or severe (92.4% vs. 78.2%, $p < 0.001$) CHD patients. No significant difference was observed between the moderate and severe CHD patient subgroups.

5.5% (40) of mild CHD patients required special assistance at school enrolment, in contrast to 14.9% (125) of moderate and 17.1% (164) of severe CHD patients. For the following analysis, the responses "Elementary school in an integration class" and "Special needs school" from Table 8 were grouped and tested against all other responses. Significant differences in special assistance received at school enrolment were observed between the following severity subgroups: mild vs. moderate (5.5% vs. 14.9%; $p < 0.001$)) and mild vs. severe (5.5% vs. 17.1%; $p < 0.001$). Mild CHD patients required special assistance at school enrolment significantly less often than moderate or severe CHD patients did. No significant difference in special assistance received was reported between the moderate and the severe CHD subpopulation. No significant sex differences were observed in the individual severity subgroups. 3.4% of CHD patients were enrolled at alternative school forms such as Waldorf schools or Montessori schools. Severe (39 patients; 4.1%) and moderate (33 patients, 3.9%) CHD patients were enrolled at these alternative school forms more frequently than mild CHD patients (2%) were (Table 8).

7% of the general population had special educational requirements between 1st and 10th grade. Most students from the general population with special assistance requirements attended special needs schools (63.9%). 1% of students from the general population attended Waldorf schools between 1st and 10th grade.

Figure 7

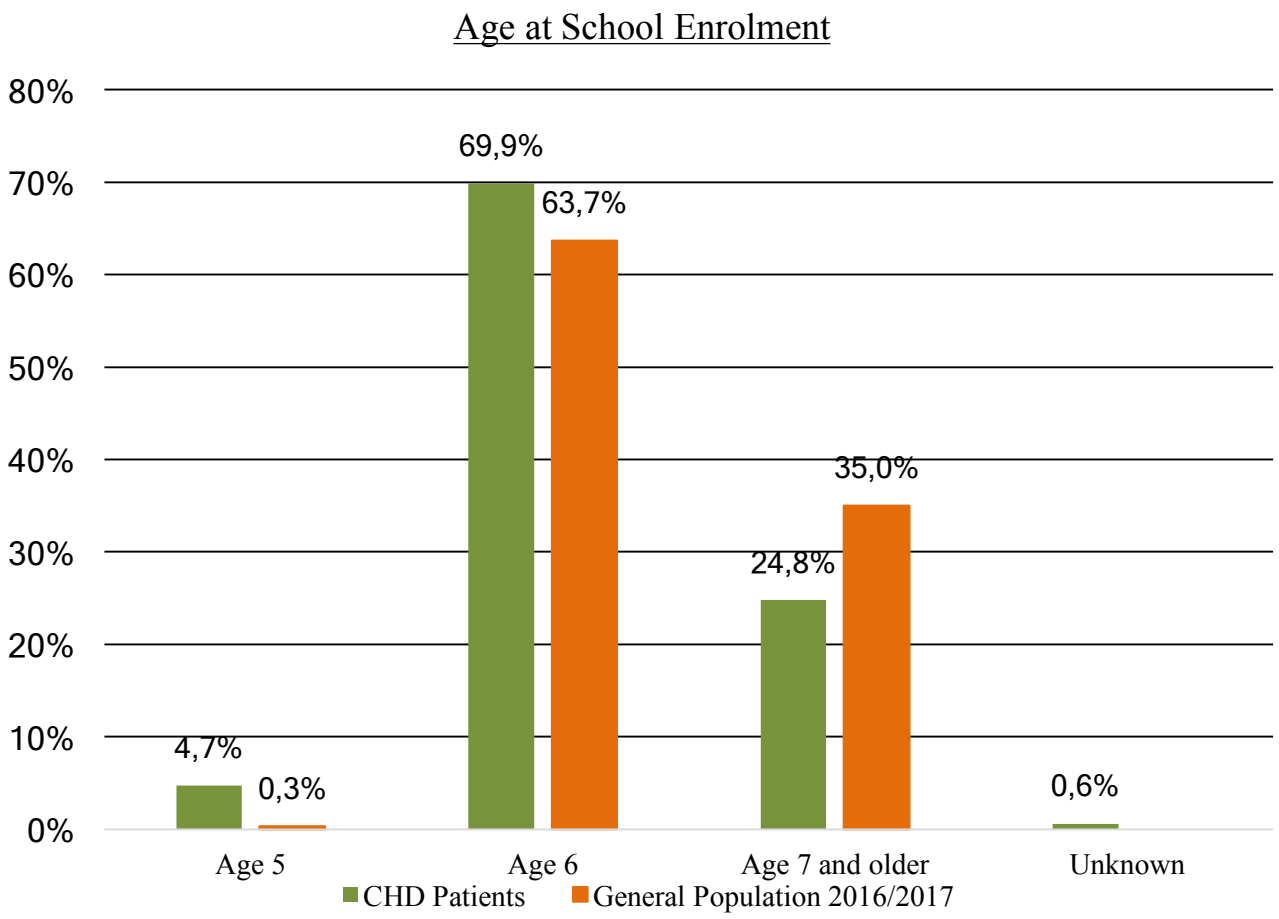

Figure 7: Patients' age at enrolment regardless of the severity of the CHD in question compared to the general population from the school year 2016/2017. Patients not yet enrolled at the time of this survey (45 patients, 16 patients = 5 years old and 29 patients = 6 years old) were excluded.

At the time of our study, 2,564 patients had been enrolled at elementary school. 45 patients (16 five-year-old and 29 six-year-old patients) had not yet been enrolled at school and were excluded from the following analyses.

98.3% (2522) of CHD patients in our study had been enrolled at school by the age of seven. 4.7% (121) of CHD patients were enrolled at the age of five, 69.9% (1,793 patients) were enrolled at the age of six, and 23.7% (608) at the age of seven. 74.6% (1,914) of CHD patients were enrolled at school at the age of six or younger. The remaining participants could either not remember the patient's exact age at enrolment (15 patients, 0.6%) or enrolled at either eight or nine years of age (27 patients, 1.1%) (Figure 7). Age at school enrolment differed significantly between female and male CHD

patients ($p < 0.001$), with more female CHD patients enrolling at the age of six or younger (76.8%, 1019 patients) than male CHD patients (69.9%, 895 patients).

In the school year 2016/2017, 0.3% of students from the general population were enrolled at school by the age of five, 64% were enrolled by the age of six and approximately 99% were enrolled by the age of seven.

Table 9

Age at School Enrolment

Age at school enrolment depending on CHD severity. Patients not yet enrolled at the time of this survey (45 patients, 16 patients age 5 and 29 patients age 6 were excluded; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 2,564)	*(n = 727)*	*(n = 827)*	*(n = 938)*	*(n = 72)*
Age 5	121 (4.7%)	50 (6.9%)	32 (3.9%)	33 (3.5%)	6 (8.3%)
Age 6	1,793 (69.9%)	553 (76.1%)	582 (70.4%)	607 (64.7%)	51 (70.8%)
Age 7	608 (23.7%)	116 (16%)	201 (24.3%)	277 (29.5%)	14 (19.4)
Age 8/9	27 (1.1%)	5 (0.7%)	8 (1%)	13 (1.4%)	1 (1.4%)
I Don't Know (IDK)	15 (0.6%)	3 (0.4%)	4 (0.5%)	8 (0.9%)	-

Age at school enrolment varied between the different CHD severity subgroups. 83.0% (603) of mild, 74.3% (614) of moderate but only 68.2% (640) of severe CHD patients were enrolled in primary school at the age of six or younger. In contrast, 30.9% (298) of severe compared to 25.3% (213) of moderate and 16.7% (124) of mild CHD patients enrolled at the age of seven or older (Table 9). A significant age difference at school enrolment was observed between the following severity groups: mild vs. moderate ($p = 0.001$) and mild vs. severe ($p < 0.001$). In a subgroup analysis a patient's sex only had a significant influence on a patient's age at school enrolment in our severe CHD patient subgroup ($p < 0.05$).

3.6. Inpatient Treatment Duration

Participants reported the duration of inpatient treatment received at hospitals or at rehabilitation facilities due to the patient's cardiac condition prior to enrolment at school. The total amount of time spent as an inpatient was relevant, regardless of whether inpatient treatment consisted of numerous short or one prolonged stay.

Figure 8

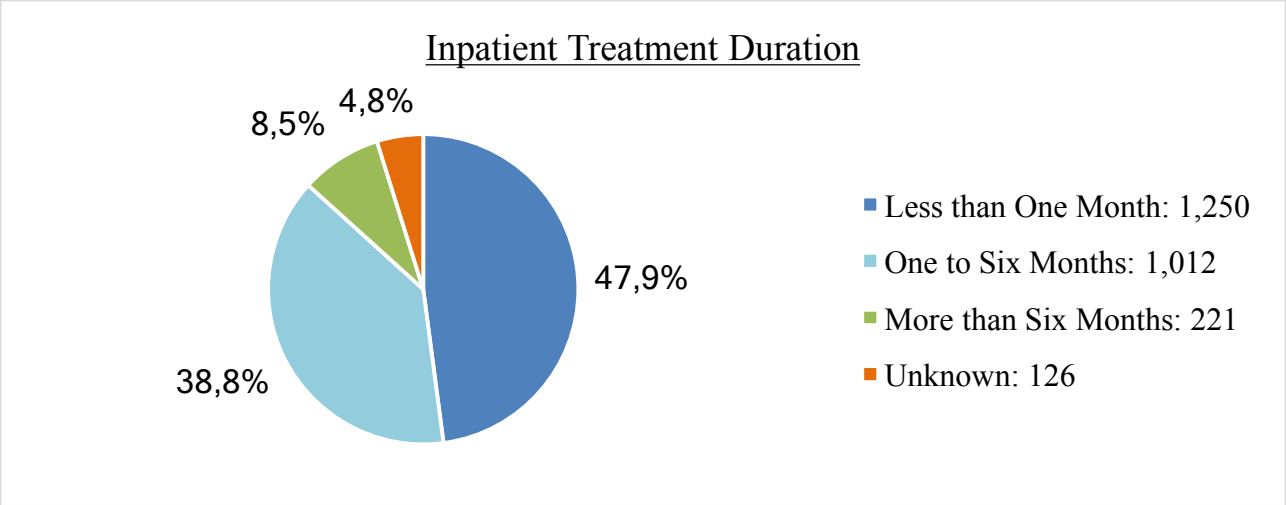

Figure 8: Total inpatient treatment duration of CHD patients regardless of CHD severity.

47.9% (1250) of patients received inpatient treatment for less than one month. 38.8% (1012) of patients received inpatient treatment for one to six months and 8.5% (221) of patients for more than six months. The remaining 4.8% (126) were no longer sure of the exact duration of hospitalization. To analyse participant's memories regarding inpatient treatment duration the response "Unknown" was tested against all other responses grouped (Figure 8). Parents remembered the duration of inpatient treatment significantly more often than patients did (98.4% vs. 90.6%; $p < 0.001$).

Figure 9

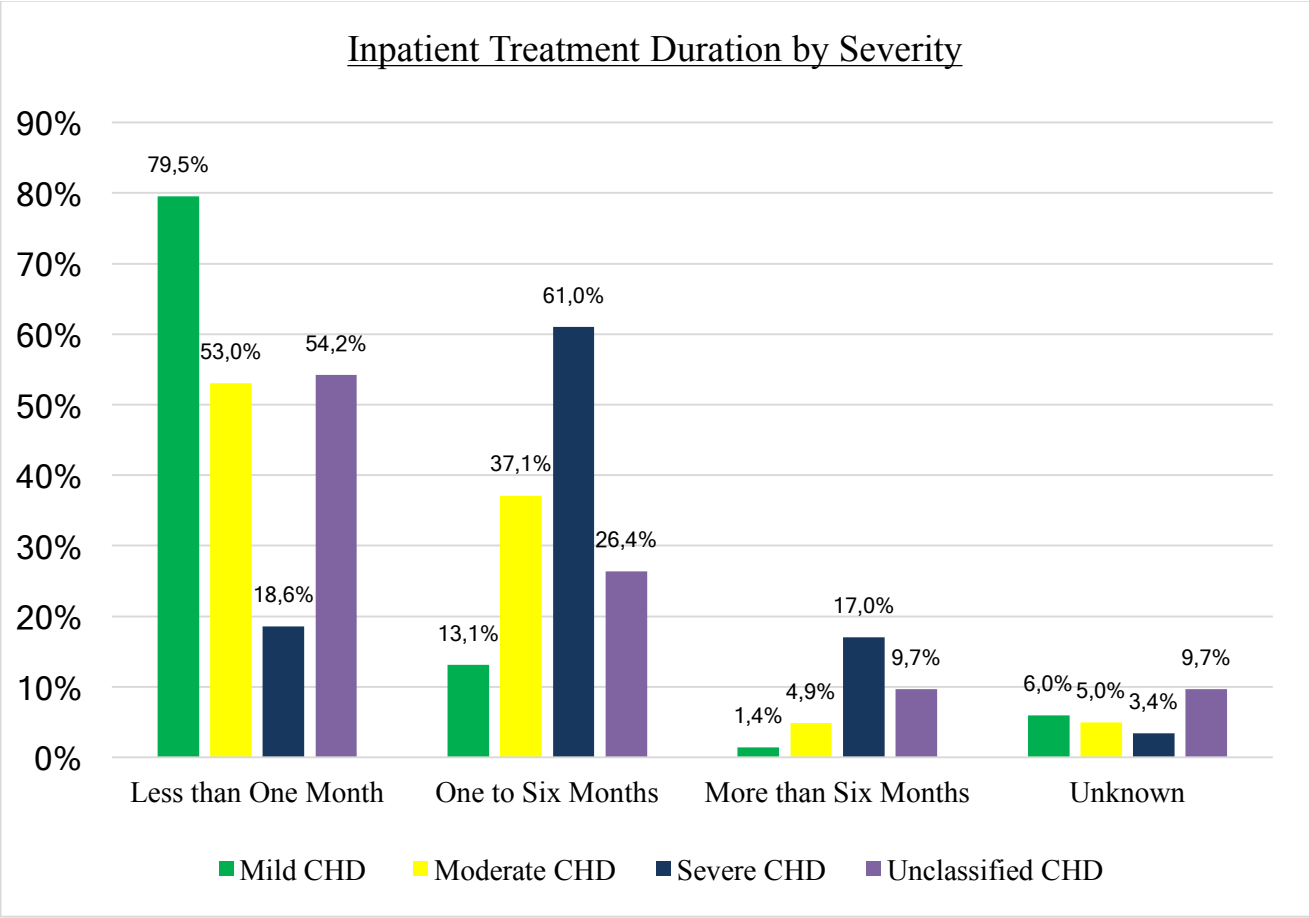

Figure 9: Inpatient treatment duration depending on severity of the underlying CHD.

Inpatient treatment duration varied between the different severity subgroups. While the majority of mild (79.5%) and moderate (53%) CHD patients spent less than one month as inpatients only a small percentage of severe CHD patients (18.6%) were able to leave hospital after such a short time period. 13.1% (97) of mild, 37.1% (312) of moderate and 61% (584) of severe CHD patients received inpatient treatment between one to six months. Inpatient treatment duration varied significantly between the following severity groups: mild vs. moderate ($p < 0.001$), mild vs. severe ($p < 0.001$), and moderate vs. severe ($p < 0.001$) (see Figure 9).

For a more exact statistical analysis of inpatient duration, the response "More than six months" from Figure 9 was tested against all other responses grouped. Significantly more severe CHD patients (17%, 163 patients) received inpatient treatment for more than six months than mild (1.4%, 10 patients; $p < 0.001$) or moderate (4.9%, 41 patients; $p < 0.001$) CHD patients. In addition, significantly more moderate CHD patients received inpatient treatment > 6 months than mild CHD patients ($p < 0.001$).

No significant difference in inpatient treatment duration according to sex was observed within the individual CHD severity subgroups. A significant difference in inpatient treatment duration according to severity was observed within both the female ($p < 0.001$) and male ($p < 0.001$) CHD patient populations.

3.7. Psychological, Behavioural and Learning Disorders

Participants reported whether the CHD patient had been diagnosed with a psychological, behavioural or learning disorder. Participants were asked to report only disorders the patients had been diagnosed with by a licensed professional (physician or psychologist).

Table 10

Prevalence of Psychological, Behavioural and Learning Disorders

Prevalence of diagnosed psychological, psychomotor, behavioural and/or learning disorders according to CHD severity; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 2,609)	*(n = 738)*	*(n = 841)*	*(n = 958)*	*(n = 72)*
Yes	870 (33.3%)	168 (22.8%)	290 (34.5%)	399 (41.6%)	13 (18.1%)
No	1,739 (66.7%)	570 (77.2%)	551 (65.5%)	559 (58.4%)	59 (81.9%)

870 (33.4%) study participants reported at least one psychological, behavioural or learning disorder (no disorder: 1,739 (66.7%); one disorder: 438 (16.7%); two disorders: 203 (7.7%); three disorders: 134 (5.1%); four disorders: 62 (2.4%); more than four disorders: 40 (1.5%)). Significantly more female (971 patients, 73.2%) than male (768 patients. 59.9%) CHD patients reported the diagnosis of one or more disorder ($p < 0.001$).

Disorder prevalence differed between the different severity subgroups. Participants reported that 22.8% (168) of mild, 34.5% (290) of moderate and 41.6% (399) of severe CHD patients had been diagnosed with at least one or more disorder. Significant differences in the rate of patients diagnosed with a psychological, behavioural or learning disorder were observed between the following severity subgroups: mild vs. moderate ($p < 0.001$), mild vs. severe ($p < 0.001$), moderate vs severe ($p < 0.005$). Mild CHD patients were diagnosed significantly less often with a disorder than moderate or severe

CHD patients and moderate were diagnosed with a disorder significantly less often than severe CHD patients were. A significant difference in the prevalence of said disorders according to CHD severity was seen within both the female and male CHD patient collectives ($p < 0.001$). At the same time, a significant difference of diagnosed disorders was observed between male and female patients in each individual CHD severity subgroup (mild: $p < 0.001$, moderate: $p < 0.001$ and severe $p < 0.001$).

Table 11

Secondary School Attendance Depending on Disorder Prevalence

Attended secondary school depending on the diagnosis of a psychological, behavioural or learning disorder. Exclusion of participants that responded with "I Don't Know", students still enrolled in primary school and students who did not attend secondary school; n = sample size.

	Diagnosed Disorder	**No Disorder**
	(n = 614)	*(n = 1315)*
Modern Secondary School Degree	61 (9.9%)	61 (4.6%)
Intermediate Secondary School Degree	111 (18.1%)	322 (24.5%)
Multi-Tiered Secondary School	43 (7.0%)	51 (3.9%)
Comprehensive Secondary School	77 (12.5%)	101 (7.7%)
Upper Level Secondary School	127 (20.7%)	695 (52.9%)
Other	195 (31.8%)	85 (6.5%)

The secondary school attended varied significantly depending on the diagnosis of a disorder by a medical professional ($p < 0.001$).

For the following statistical analysis, the response "Upper Level Secondary School" was tested against all other options from Table 11 grouped. Patients diagnosed with a psychological, behavioural or learning disorder were significantly less likely to attend upper level secondary schools ($p < 0.001$). More than half of CHD patients without a diagnosed disorder attended an upper level secondary school (52.9%, 695 students), in comparison to only 20.7% (127 patients) of students with a diagnosed disorder.

3.8. School Careers

3.8.1. Secondary School Form

Figure 10

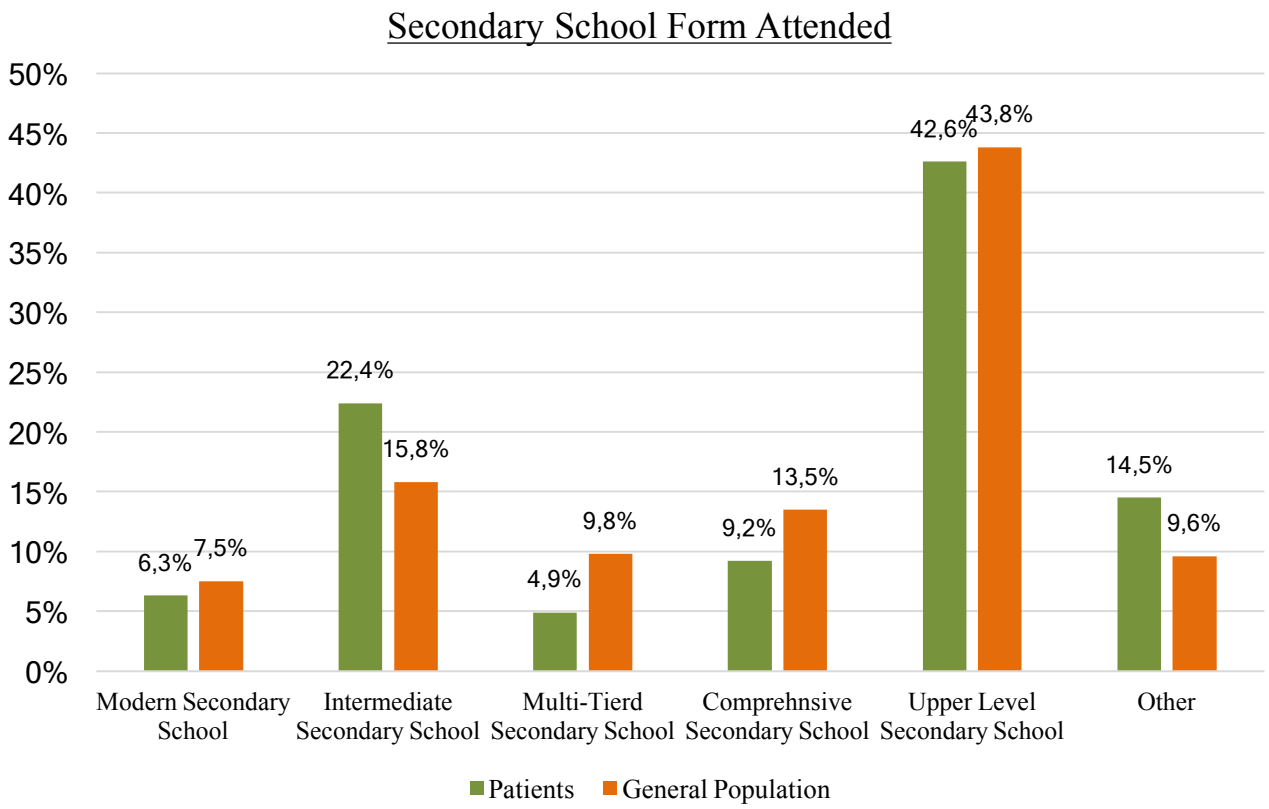

Figure 10: Secondary school attendance of CHD patient compared to the general population in 2016/2017. 680 patients were not yet attending secondary school at the time of this study or were no longer sure of the secondary school they attended and were excluded from this analysis; = 1929. All children from the general population attending a special needs school or secondary school level I/II in the school year 2016/2017 were included.

Of the 2,609 patients in our study cohort, 1,929 (75.7%) were attending a secondary school or had completed their secondary school education at the time of this survey. For the following statistical analyses, all students not yet enrolled in secondary school or who had responded with "I Don't Know" were excluded.

After elementary school, 6.3% (122) of CHD patients attended a modern secondary school ("Hauptschule") and 22.4% (433) continued their school careers at an intermediate level secondary

school (“Realschule”). 4.9% (94) of CHD patients attended a multi-tiered secondary school, while 9.2% (178) of CHD patients attended a comprehensive school. The most commonly attended secondary school form was the upper level secondary school (“Gymnasium”). 42.6% (822) of CHD patients from our patient cohort attended upper level secondary schools after primary school.
The secondary school from attended varied significantly between male and female patients ($p < 0.05$). For a more exact statistical analysis, the response “Upper Level Secondary School” from Table 12 was tested against all other responses grouped. Significantly more female (446 patients, 44.8%) than male (376 patients, 40.3%) CHD patients attended upper level secondary schools ($p < 0.05$).

In the school year 2016/2017, 7.5% of students from the general population attended modern secondary schools, 15.8% attended intermediate secondary schools, 43.8% attended upper level secondary schools, 9.8% of students attended a multi-tier secondary school, and 13.5% attended a comprehensive school (Figure 10).

Table 12

Secondary School Attendance

Secondary school form attended according to CHD severity. Exclusion of all not enrolled in secondary school or unsure of secondary school form attended; n= sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 1,929)	*(n = 517)*	*(n = 643)*	*(n = 712)*	*(n = 57)*
Modern Secondary School (Hauptschule)	122 (6.3%)	29 (5.6%)	44 (6.8%)	48 (6.7%)	1 (1.8%)
Intermediate Secondary School (Realschule)	433 (22.5%)	103 (19.9%)	146 (22.7%)	168 (23.6%)	16 (28.1%)
Multi-Tier Secondary School Forms	94 (4.9%)	22 (4.3%)	23 (3.6%)	46 (6.5%)	3 (5.3%)
Comprehensive Schools	178 (9.2%)	53 (10.3%)	56 (8.7%)	66 (9.3%)	3 (5.3%)
Upper Level Secondary School	822 (42.6%)	263 (50.9%)	277 (43.1%)	250 (35.1%)	32 (56.1%)
Another School Form	280 (14.5%)	47 (9.1%)	97 (15.1%)	134 (18.8%)	2 (3.5%)

50.9% (263) of mild, 43.1% (277) of moderate but only 35.1% (250) of severe CHD patients attended upper level secondary schools. For a more exact statistical analysis, the response "Upper Level Secondary School" from Table 12 was tested against all other responses grouped. A significant difference in the attendance frequency of upper level secondary schools was observed between the following severity subgroups: mild vs. moderate ($p < 0.01$), mild vs. severe ($p < 0.001$), moderate vs. severe ($p < 0.005$). Patients with mild CHDs attended upper level secondary schools significantly more often than patients with moderate or severe underlying CHDs. A significant difference in upper level secondary school attendance rates according to severity was observed in both the male ($p < 0.005$) and female ($p < 0.001$) CHD patient subgroup.

In comparison, academically less challenging secondary school forms were more commonly attended by patients in the more severe CHD subgroups. 29.8% (154) of mild, 33.1% (213) of moderate and 36.7% (262) of severe CHD patients attended school forms where the final degrees were either a modern or an intermediate secondary school degree. For a statistical analysis, the responses "Modern Secondary School", "Intermediate Secondary School" and "Multi-Tiered Secondary School" from

Table 12 were grouped and tested against all other responses. A significant difference was only observed between the mild and severe CHD patient subgroups ($p < 0.05$).

3.8.2. School Year Repetition

Table 13

School Year Repetition Prevalence

The prevalence of CHD patients that repeated a school year according to their sex. Exclusion of patients not yet enrolled in school (45); n = sample size.

	Total sample	**Male Students**	**Female Students**
	(n = 2,564)	*(n = 1,282)*	*(n = 1,327)*
One or More Grades Repeated	288 (11.2%)	157 (12.4%)	131 (10.1%)
No Grade Repeated	2,271 (86.6%)	1,102 (87.3 %)	1,169 (89.9%)
I Don't Know (IDK)	5 (0.2%)	4 (0.4%)	14 (0.1%)

Participants reported that 11.2% (288) of CHD patients repeated at least one school year in either elementary or secondary school. More male CHD patients (12.4%; 157) than female CHD patients (10.1%; 131) repeated a school year, though the observed difference was not significant (Table 13). In the school year 2016/2017, 2.3% of students from the general population repeated a grade, with more male (2.8%) than female students (1.8%) repeating a school year.

Figure 11

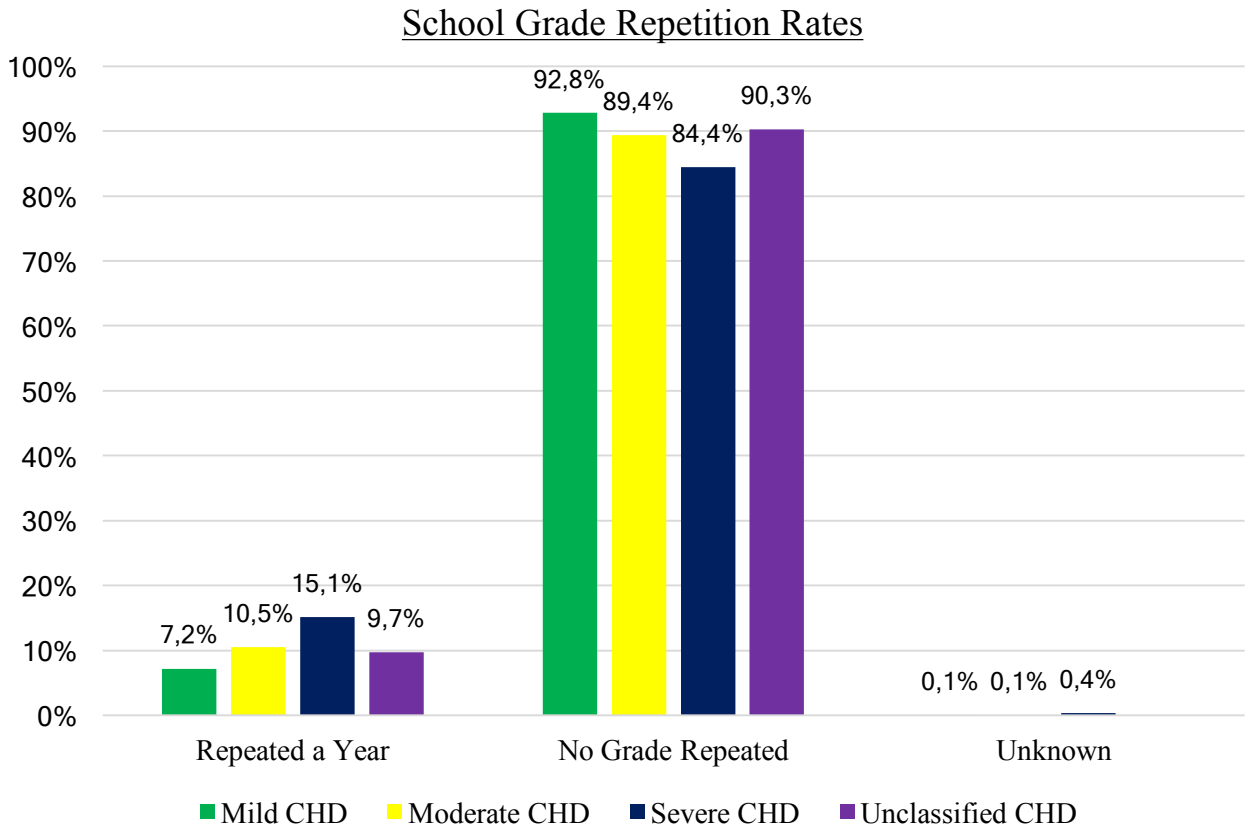

Figure 11: Prevalence of CHD patient school year repetition according to the severity of the underlying CHD. Patients not yet enrolled at school were excluded (45 patients).

The likelihood of repeating a school year differed depending on the severity of the underlying CHD. 7.2% (52) of mild, 10.5% (87) of moderate and 15.1% (142) of severe CHD patients repeated at least one school year. Severe CHD patients were twice more likely to have to repeat a school year than mild CHD patients were. For the following statistical analyses, the response "Repeated a Year" was tested against the responses "No Grade Repeated" and "Unknown" grouped (Figure 11). Significant differences in the number of patients who repeated a school year were observed between the following severity subgroups: mild vs. moderate ($p < 0.05$), mild vs. severe ($p < 0.001$) and moderate vs. severe ($p < 0.01$). Severe CHD patients repeated a school year significantly more often than mild or moderate CHD patients did and moderate CHD patients repeated a year significantly more often than mild CHD patients did.

Table 14

School Grade Repetition According to Disorder Prevalence

Participants that did not know if the patient had repeated a school year (5 patients) were added to the "No School Year Repeated" group. Patients not yet enrolled in school were excluded; n = sample size.

	Diagnosed Disorder	**No Disorder**
	(n = 848)	*(n = 1716)*
School Year Repeated	162 (19.1%)	126 (7.3%)
No School Year Repeated	686 (80.9%)	1590 (92.7%)

The diagnosis of a psychological, behavioural or learning disorder as well as the duration of inpatient treatment significantly influenced the frequency of school year repetition (Table 14 and Table 15). Patients suffering from one or more psychological, learning or behavioural disorders repeated a grade significantly more often than patients with no diagnosed disorder did ($p < 0.001$, Table 14). The diagnosis of a disorder significantly increased the school year repetition rates regardless of the severity of the underlying CHD (mild, moderate, and severe: $p < 0.001$).

Table 15

School Grade Repetition According to Inpatient Treatment Duration

Participants that did not know if the patient had repeated a school year (5 patients) were added to the "No School Year Repeated" group. Patients not yet enrolled in school were excluded; n = sample size.

	Inpatient Treatment > 6 Months	**Inpatient Treatment < 6 Months**
	(n = 212)	*(n = 2352)*
School Year Repeated	50 (23.6%)	238 (10.1%)
No School Year Repeated	160 (80.9%)	2111 (92.7%)

A hospital stay > 6 months significantly increased the likelihood of repeating a grade (23.6% vs. 10.1%; $p < 0.001$, Table 15). Inpatient treatment > 6 months did not have a significant influence on the mild CHD patient subgroup. However, in the moderate and severe CHD patient subgroups

inpatient treatment duration significantly influenced the likelihood with which patients repeated a school year ($p < 0.001$; $p < 0.05$).

3.8.3. Additional School Support

Table 16

Additional School Support

Additional school support received according to CHD severity. The tutored subject matter tutored was not determined; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 2,609)	*(n = 738)*	*(n = 841)*	*(n = 958)*	*(n = 72)*
Yes	731 (28%)	145 (19.6%)	240 (28.5%)	329 (34.3%)	17 (23.6%)
No	1,823 (69.9%)	583 (79%)	583 (69.3%)	603 (62.9%)	54 (75%)
I Don't Know (IDK)	55 (2.1%)	10 (1.4%)	18 (2.1%)	26 (2.7%)	1 (1.4%)

Participants reported that 28% (731) of CHD patients received additional tutoring for a school subject on a regular basis for more than three months. A significant difference in after-school tutoring rates was observed between both sexes ($p < 0.001$) with 32% (410) of male but only 24.2% (321) of female CHD patients having received or receiving after-school tutoring.

The underlying severity of the patient's CHD had a significant influence on the likelihood of receiving extra tutoring. 9.6% (145) of mild, 28.5% (240) of moderate and 32.3% (329) of severe CHD patients received additional tutoring. For the following statistical analysis the responses "No" and "IDK" from Table 16 were grouped and tested against "Yes". Mild CHD patients received significantly less extra after-school tutoring than their peers from the moderate ($p < 0.001$) and severe ($p < 0.001$) CHD patient groups and moderate CHD patients received significantly less after-school tutoring than severe CHD patients ($p < 0.05$). A significant difference in after-school tutoring rates according to severity was observed in both the female ($p < 0.001$) and male ($p < 0.01$) patient subgroups.

The amount of additional school support received by CHD patients varied significantly depending on the secondary school form ($p < 0.001$). 13.3% (109) of students attending upper level secondary

schools received after-school tutoring compared to 30.5% (198) of students attending modern, intermediate or multi-tiered secondary schools. Patients attending upper level secondary schools and upper level secondary school graduates were less likely to have received after-school tutoring than CHD patients attending academically lower ranked secondary school forms (intermediate, modern or multi-tiered secondary schools) were.

3.8.4. Secondary School Graduation

819 patients (31.4%) had dropped out of or graduated from secondary school at the time of our study. Only patients above the age of 15 were statistically analysed because school attendance is compulsory up to this age.

Figure 12

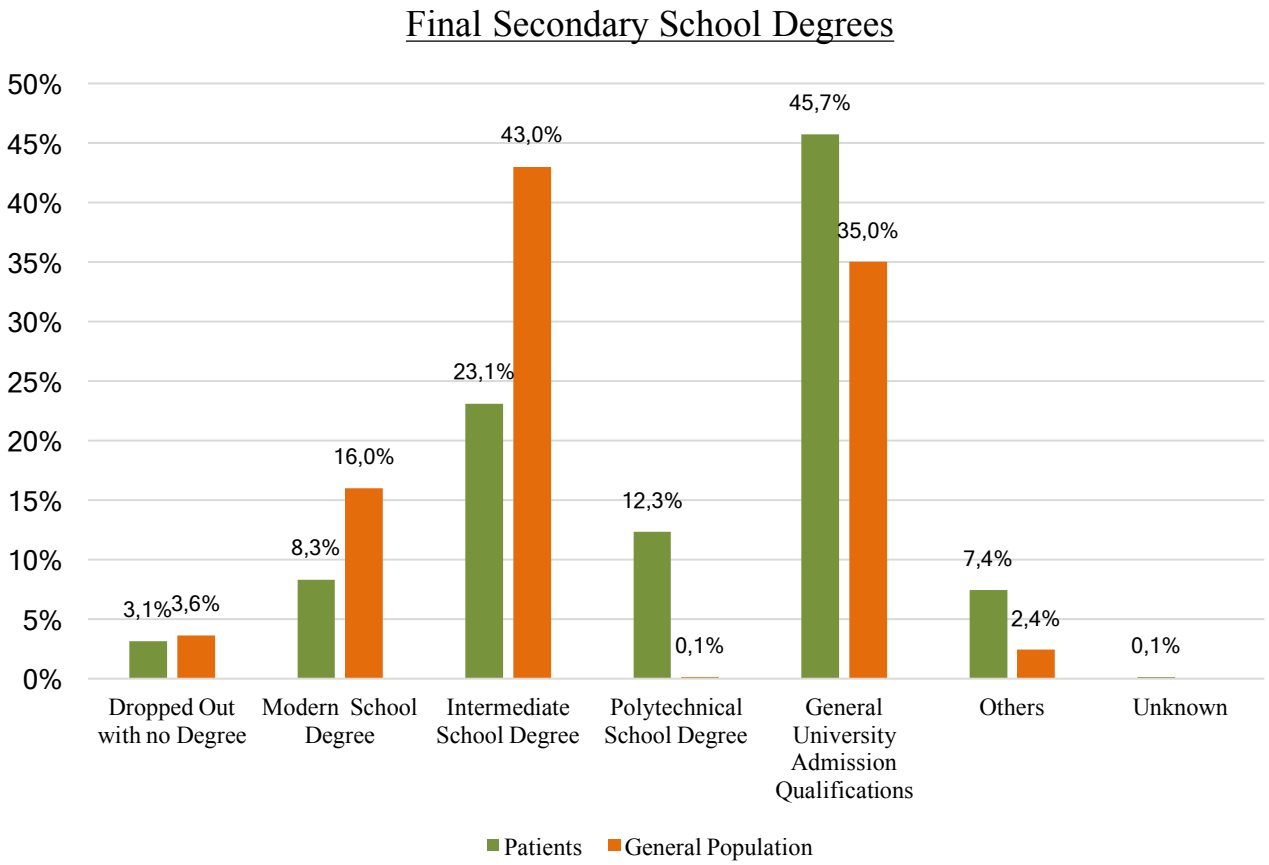

Figure 12: The final secondary school degrees of CHD patients upon graduation compared to students from the general population in the school year 2016/2017.

3.1% (25) of CHD patients dropped out of school without acquiring a school degree. 8.3% (68) of CHD patients graduated from secondary school with a modern (Hauptschulabschluss) and 23.1% (189) graduated with an intermediate secondary school diploma (Realschulabschluss). 45.7% (374) of CHD patients graduated from an upper level secondary school or from a comprehensive school with the general university admission qualifications (Abitur) and 12.3% (101) of CHD patients graduated with the polytechnical secondary school degree (Fachabitur). The final degree ascertained varied significantly depending on the patient's sex ($p < 0.005$). For a more exact analysis, the response "General University Admission Qualifications" was tested against all other responses grouped (Figure 12). Significantly more female (221; 48.9%) than male (153; 41.7%) CHD patients graduated with "Abitur" ($p < 0.05$).

In the 2016/2017 school year students from the general population graduated from secondary school with the following degrees: no major secondary school degree 6%, modern secondary school degree 16%, intermediate secondary school degree 43%, polytechnical secondary school degree 0.1%, and general university admission qualifications 35%.

6% of students left secondary school with no major secondary school degree. However, 2.4% graduated with a degree for the learning or mentally disabled and only 3.6% truly dropped out of secondary school with no degree.

In 2016/2017, 52% of all school graduates attained higher education entrance qualifications. 41% of all graduates received the general university admission qualifications and 11% graduated with the polytechnical school degree. A significant number of students from the general population attained these degrees at trade schools or during their apprenticeships as part of their post-secondary school education and did not graduate directly from secondary school with these degrees.

Table 17

Final Secondary School Degree according to CHD Severity

Analysis of the final secondary school qualifications received by patients according to the severity of their underlying CHD. Only study participants between the ages of 15 and 25 were statistically analysed; n = sample size.

	Total Sample	**Mild CHD**	**Moderate CHD**	**Severe CHD**	**Unclassified CHD**
	(n = 819)	*(n = 192)*	*(n = 283)*	*(n = 313)*	*(n = 31)*
Left School without a School Certificate	25 (3.1%)	-	12 (4.2%)	13 (4.2%)	-
Modern Degree	68 (8.3%)	16 (8.3%)	20 (7.1%)	31 (9.4%)	1 (3.2%)
Intermediate Degree (RSA)	189 (23.1%)	36 (18.8%)	58 (20.5%)	87 (27.8%)	8 (25.8%)
Polytechnic School Degree (fHSR)	101 (12.3%)	20 (10.4%)	38 (13.4%)	41 (13.1%)	2 (6.5%)
Abitur (aHSR)	374 (45.7%)	110 (57.3%)	134 (47.3%)	110 (35.1%)	20 (64.5%)
Another School Degree	61 (7.4%)	9 (4.7%)	21 (7.4%)	31 (9.9%)	-
I Don't Know (IDK)	1 (0.1%)	1 (1%)	-	-	-

CHD severity had a significant influence on the secondary school degree received at graduation ($p < 0.001$). All mild CHD patients in our study cohort graduated from secondary school with a school degree in contrast to 4.2% (25 patients) of moderate and severe CHD patients who dropped out of secondary school without receiving any diploma. Modern secondary school degrees were attained with similar frequency by each CHD severity subgroup: 8.3% (16) of mild, 7.1% (20) of moderate and 9.4% (31) of severe CHD patients. Differences were observed in the rate with which the individual subgroups graduated with the intermediate secondary school degree: 18.8% (36) of mild, 20.5% (58) of moderate and 27.8% (87) of severe CHD patients.

For a more exact statistical analysis the response "Intermediate Degree" from Table 17 was tested against all other responses grouped. Severe CHD patients were significantly more likely to graduate with an intermediate secondary school degree than mild ($p < 0.05$) or moderate ($p < 0.05$) CHD

patients were. No significant difference was observed between the mild and moderate CHD patient subgroups.

67.7% (130) of mild, 60.7% (172) of moderate but only 48.2% (151) of severe CHD patients graduated from secondary school with higher education entrance qualifications ("Abitur" or "Polytechnical School Degree", Table 17). For the following analysis, the responses "Abitur" and "Polytechnical School Degree" from Table 17 were grouped and tested against all other responses grouped. Significant differences were observed amongst graduation rates of CHD patients with higher education entrance qualifications between the following subgroups: mild vs. severe: $p < 0.001$ and moderate vs. severe: $p < 0.005$. Patients with a severe underlying CHD were significantly less likely to graduate with the qualifications required to study at a university or at a university of applied science than mild or moderate CHD patients were. CHD severity had a significant negative impact on a CHD patient's secondary school degree at graduation.

4. Discussion

In the presented cross-sectional study, we could demonstrate that the majority of participating CHD patients experienced a standard school career. However, school form and age at enrolment and the final school degree attained varied depending on the severity of the underlying CHD. Patients were more likely to be diagnosed with a psychological disorder and/or forced to repeat a class if their CHD was more severe. These aspects will be elaborated on in the following paragraphs.

4.1. Participation Rates

Of the 22,126 patients and families initially invited to participate only 3,605 (16.3%) accessed the link provided in the email or letter. Therefore, we can only confirm that 3,605 families actually received a participation invitation. Patients and families that change their home or email address have to contact the NRCHD and update their contact information of their own volition. It is unclear how diligently postal and email addresses are updated by patients or their guardians. The final response rate of our study after exclusions (2,609 surveys/ 11.8%) was lower than in previous studies conducted through the database of the NRCHD(7, 52, 56, 104).

The timing of our survey may have negatively influenced the final participation rate. The survey was carried out during the school summer holidays of numerous federal states. In addition, the survey addressed a very broadly defined CHD patient group. Patients between the ages of five and twenty-five years and regardless of their diagnosed CHDs were invited to participate in our study. The survey dealt with a variety of different subjects pertaining to CHD patients, their upbringing and their school careers. Due to the broad nature of this survey, patients may not have seen a direct personal benefit in their participation. Previous surveys performed by the NRCHD addressed more narrowly defined participant groups and more specific cardiac health issues.

The correct completion of the survey took between 10 and 15 minutes and consisted of up to 42 questions. The extent and length of our survey may have fazed possible participants. A large portion of patients invited to participate were transitioning into adulthood. In this specific age group patients frequently fail to attend follow-up examinations and participation rates tend to be low on average(48, 49). Thanks to our large patient cohort, a final response rate of 11.8% was deemed sufficient for an adequate statistical analysis. However, a low response rate increases the risk of a potential selection bias and this must be taken into consideration when reaching conclusions (see 5. Limitations).

Significantly more female patients and mothers in deputy of their predominantly male children completed the online questionnaire. Higher female participation in online surveys is a previously described and well-known phenomenon(53, 111). Women are more likely to participate in surveys and are typically more vested and involved in matters concerning their own health and that of their children. Higher female participation rates were expected and did not negatively impact the information attained.

4.2. CHD Severity Comparison

A high percentage of patients included in our study suffered from CHDs classified as moderate or severe (68.9% of patients). In the general population, mild CHDs are more common than moderate or severe CHDs(3, 4). In our study population, there was an overrepresentation of patients with moderate and severe CHDs, compared to the prevalence of these CHDs in large European prevalence studies and within the database of the NRCHD(3, 4, 8, 10). Especially male severe CHD patients were disproportionally overrepresented in our study. In other studies, mild CHDs account for up to 80% of all CHDs in the general population depending on the nature of the study and the classification algorithm employed(3-5, 7, 8, 10). In contrast, only 28.3% of patients recruited in our study had been diagnosed with a mild CHD, making them the smallest severity subgroup, while the severe CHD subpopulation was the largest consisting of 36.7% of patients in our study.

The most frequent CHDs are typically the ventricle septum defect (VSD) followed by the atrial septum defect (ASD) (3, 4, 7, 8) whereas only 20.5% of CHD patients in our study population suffered from a VSD and only 10% suffered from an ASD. The second and third most common CHDs were classified as severe CHDs (univentricular heart defect 11.7% / Tetralogy of Fallot 11.1%). These severe CHDs are less common in the general population and in the NRCHD database. The different prevalence of the individual CHDs explains the unequal sex distribution within the severity subgroups in our study. The high prevalence of mild CHDs in the general population can be explained with the higher birth rate of patients with mild defects in general combined with lower mortality rates and less complications within this patient group(4).

The overrepresentation of moderate and severe CHD patients may be due to the nature of our study and in part due to the database used to recruit patients. Patients with more severe CHDs and their parents are disproportionately more inclined to participate in studies because their lives are more strongly impacted and limited by the underlying CHD. A severe CHD patient's life revolves around

their heart defect and its treatment to a greater extent than that of a mild CHD patient. Therefore, patients with more severe underlying CHDs are more vested in improving treatment and benefit most from studies aimed at analysing and improving their situation. Severe CHD patients are more likely to experience abnormal school careers, which in turn might increase their likelihood of participating(17, 38, 97, 103).

Mild CHD patients often receive minimally invasive treatment at a young age. After initial treatment, mild CHD patients are rarely confronted with complications concerning their CHD or its treatment. High rates of spontaneous closure of ASDs and VSDs have been reported in the mild CHD population(18). These CHDs never become clinically apparent and therefore these patients are not enrolled in the NRCHD database.

Secondly, there already is an overrepresentation of patients suffering from moderate and severe CHDs in the database of the NRCHD(10). The NRCHD is a clinical database meaning that only CHD patients in clinical observation and/or treatment can enrol. Patients more strongly limited in their everyday lives are more inclined to allow the NRCHD to save and use their medical information for potential studies.

We deemed the overrepresentation of patients suffering from moderate and severe CHDs in our study as beneficial for statistical analyses. Numerous studies have reported that especially patients diagnosed with moderate and severe CHDs are at risk for developmental delays and neurodevelopmental deficiencies(17, 71, 74, 78, 85). Therefore, below-average school careers were more likely to be prevalent in these severity subgroups. High patient recruitment numbers in the more severe severity subgroups permitted a more precise statistical analysis of possible school problems and academic difficulties.

4.3. Prenatal Diagnosis Rate Development

17.3% (451) of participants reported on a prenatal diagnosis of their CHD. This self-reported prenatal detection rate can be regarded as low average when compared to other large European studies with observed prenatal diagnosis rates of 12-45% depending on the country, patient collective and CHD in question(7, 21-26). Prenatal detection rates of severe CHDs have been reported to be as high as 80%(3, 30, 31). Existing studies often focus on the prenatal diagnosis rates of more severe CHD cases, where

a prenatal diagnosis influences delivery and debatably the outcome. In addition, we observed an extended period of time over which diagnosis rates have significantly improved.

Self-reporting as a method to gather data regarding prenatal diagnosis rates has been criticized as inaccurate in the past. Parents may not recall a prenatal diagnosis or might not have understood the significance of the diagnosis at the time of the examination. It has been argued that asking mothers and patients to report the occurrence of prenatal diagnoses may lead to an underreporting and to a reporting bias. For mothers this hypothesis has been disproven. Expectant mothers have described receiving a prenatal CHD diagnosis as traumatic and a prenatal diagnosis has been attributed to high levels of maternal stress and anxiety(23, 42). Accordingly, parents and especially mothers rarely forgot whether and when a CHD was diagnosed and often remember the exact date of the diagnosis years after their child's birth.

To our knowledge no studies exist that have analysed the accuracy of patient knowledge regarding the time of diagnosis of their own CHD. Patients become more involved in matters regarding their cardiac health later on in life, usually when they reach puberty and become more independent(48, 49). The exact time at which the CHD was diagnosed is of little interest to patients, as it no longer has an influence on their treatment during puberty and adulthood. Less prenatal diagnoses were reported to have taken place in our patient subgroup than in our parent subgroup (11.1% vs. 21.6% respectively) and patients more often answered the question with "I Don't Know" (6.5% vs. 0.6% respectively). It is probable that patients negated the occurrence of a prenatal diagnosis if their parents had not adequately informed them about it. Patients being unable to state the time of diagnosis underlines a lack of communication between physicians, parents and patients that has previously been described(48). During childhood and adolescence, patients are frequently left out of decision-making processes regarding their health and treatment. Parents aim to protect their children from unpleasant situations and attempt to shield them from aspects concerning their cardiac health (86, 87). However, this behaviour causes patients to become more dependent upon their parents and less autonomous as can be seen by the high percentage of patients that did not know the exact time of the diagnosis nor the duration of inpatient treatment. Overbearing parenting can foster disinterest and can increase the lack of information patients have regarding their underlying CHD(48, 49).

These initial results emphasize the need for patients to be more strongly involved in decision-making processes concerning their CHD and at a younger age. Early involvement can help patients better understand their condition, and can prevent misconceptions regarding their limitations. Ideally, this

will enable patients to lead more autonomous lives. Though it is understandable that parents should try to shield their children from the negative aspects of their cardiac health, overprotective behaviour exhibited by parents of chronically ill patients can have a detrimental effect in the long run (86).

Severe CHDs were reported to have been diagnosed prenatally significantly more often than moderate or mild CHDs (27.7% vs. 13.6% and 27.7% vs. 7.9% respectively), a phenomenon reported in numerous studies(3, 7, 21, 23).

Higher prenatal diagnosis rates within the moderate and severe CHD patient subgroups can be attributed to numerous factors. More severe CHDs are usually associated with greater anatomical pathologies, which in turn allow for an easier detection during prenatal ultrasound examinations. Mild CHDs, usually associated with minor anatomical pathologies, are overlooked more easily and rarely have a negative influence on the intrauterine growth of the foetus. In addition, severe CHDs more commonly manifest themselves in high risk pregnancies(30). As a result, high risk pregnancies are usually monitored more closely and in specialized tertiary care centres. Here gynaecologists and paediatricians have access to better equipment and tend to be more experienced concerning prenatal examination techniques.

Higher self-reported prenatal diagnosis rates of moderate and severe CHDs may in part be attributed to the more traumatic and unsettling nature of such a diagnosis for parents(42). The diagnosis of a severe CHD often goes hand in hand with considerations concerning the termination of pregnancy (TOP) (30). Higher levels of stress associated with such a diagnosis make it easier for parents to remember it decades later.

Examined in five-year-intervals prenatal diagnosis rates improved in steady increments between 1992 and 2011. Patients were more than three times as likely to receive a prenatal diagnosis in the years 2007-2011 than they were in the years 1992-1996 (1992-1996: 6.9% vs. 2007-2011: 26.2%). Other studies have observed similar increases in the prenatal diagnosis rates of CHD patients in the past decades(12, 27). Improved diagnosis rates have been attributed to better ultrasound technology, higher examination frequency and increased awareness of the treating physician and patients regarding congenital diseases (12, 27, 29).

A possible reporting bias should be taken into consideration when interpreting the drastic improvement of prenatal diagnosis rates between 1992 and 2011. While improved examination techniques and diagnostic tools can explain the increased rate of prenatal diagnoses to an extent,

reported improvements may be exaggerated. In our study, patients may have negated the occurrence of a prenatal diagnosis if they had forgotten the exact time of diagnosis. It is likely that participants reporting the occurrence of more recent prenatal diagnoses remembered more accurately.

Increased awareness of birth defects combined with improved diagnosis rates have led to a significant increase in the number of pregnancies terminated due to CHDs(12, 30).

This emphasizes the importance of longitudinal long-term studies focused on CHD patients that analyse the cumulative effect of NDs and DDs on a patient's life. Physicians must aim to prevent TOPs based on misinformation and unfounded fears. The majority of the patients included in our study were able to enjoy a normal school career and were able to graduate with a normal secondary school degree. Extensive knowledge in the area of long-term complications may reduce the absolute amount of pregnancies terminated.

A multidisciplinary team consisting of cardiologists, psychiatrists and gynaecologists should accompany and help guide the patient through the difficult decision making process and must make sure that she can make an educated decision. Longitudinal studies can alleviate expectant parents' unfounded fears concerning their child's later health, education and QoL. These aspects underline the importance of our study.

The extent of benefits offered by a prenatal diagnosis remain highly disputed with numerous studies reporting contradictory findings concerning complication rates, inpatient treatment duration and overall mortality(12, 20, 25, 27, 32-38). Theoretically, a prenatal diagnosis allows the treating physician to make adequate preparations to minimize the chance of any complications and to ensure a healthy and safe delivery. Physicians with higher levels of expertise and training can deliver prenatally diagnosed children in tertiary care centres. This should reduce the likelihood of long-term complications and overall-mortality(20).

To date a key endpoint when analysing the effects of a prenatal diagnosis has been the one-year mortality rate(22, 25). Long-term studies with new endpoints need to be designed and carried out to better determine the true benefits of a prenatal diagnosis. In our study the occurrence of a prenatal diagnosis did not have a significant impact on the final secondary degree attained and no clear benefit concerning a patient's school careers was observed.

The fact that only 17.3% of CHDs patients in our study cohort were prenatally diagnosed emphasizes the need for the further development and implementation of standardized prenatal detection

examinations nationwide. Though the improvements observed were promising (1992-1996: 6.9% vs. 20017-2011: 26.2%) the prenatal diagnosis rates were still subpar considering current diagnostical possibilities. German prenatal diagnosis rates need to continue to improve drastically in the coming years.

4.4. Impact of Inpatient Treatment Duration

Duration of inpatient treatment varied greatly depending on the severity of the patient's underlying CHD and on the complexity and invasiveness of the surgery required. Especially severe CHD patients were at risk for extended periods of hospitalization of over six months.

Numerous studies have identified inpatient treatment duration as an independent risk factor for neurodevelopmental deficiencies and developmental delays(78, 82, 89). Patients who spend extended periods growing up in a hospital environment are less likely to experience a normal childhood. Social and playful interactions with peers in a safe environment are essential for a child's healthy development. In our study extended periods of inpatient treatment correlated with patients more frequently having to repeat a grade and with an increased prevalence of psychological, behavioural or learning disorders regardless of the severity of the patient's underlying CHD. Extended periods of inpatient treatment must be regarded as an independent risk factor for pathological development, which in turn can later lead to difficulties at school. Physicians must aim to prevent extended inpatient treatment whenever medically feasible and responsible. A healthy, familiar and safe environment plays a key role for the physiological development of a child. In our study it was difficult to analyse inpatient treatment duration as an independent risk factor because longer inpatient treatment nearly always went hand in hand with increased CHD severity.

4.5. Implementation of Early Interventional Therapy

In our study, 51.2% of CHD patients received some form of early childhood supportive therapy. Supportive treatment measures were defined as occupational, physical or speech therapy before school enrolment. Patients with more severe CHDs were more likely to receive early interventional therapy. Von Rhein et al. observed similar high rates of interventional therapy within their patient cohort (78). Studies have reported on the high prevalence of DDs and NDs, ranging from mild to severe within the CHD patient community. Subtle, often even subclinical delays and deficiencies have been observed in the following domains when comparing CHD patients to the general population: attention

span, visual motor integration, visual construction and perception, fine and gross motor skills, attention, hand-eye-coordination, impulse-restriction, reasoning, language, social cognition, intellect and executive function(17, 61, 74, 78, 85). It is likely that the high rate of early supportive therapy measures within the CHD patient cohort was due to the high prevalence of NDs and DDs. This was reflected by the fact that predominantly severe CHD patients received early interventional therapy. The high prevalence of interventional therapies shows an increased awareness among parents and treating physicians for possible developmental problems. In addition, CHD patients are monitored closely, especially during childhood and after surgical interventions. Patients have numerous follow-up examinations and a more intense and prolonged contact to a paediatrician compared to their healthy peers in the general population. This extensive longitudinal contact allows treating physicians a more close and thorough examination of a patient's development. Subsequently physicians can more easily diagnose mild and subclinical developmental delays and are more likely to see the need for early supportive therapy. Treating paediatricians may also have lower inhibition thresholds when it comes to prescribing early supportive therapy measures for CHD patients. At the same time, children in the general population with similar DDs and NDs may not be diagnosed with the same frequency due to less extensive and less regular contact to a physician and greater inhibition thresholds.

Factors such as neurological development play a large role when evaluating the success of CHD patient treatment. This focus shift has increased physician and parent sensitivity in the area of supportive therapy and shows itself in the high prescription rates of early supportive treatment in our study.

There is a lack of studies that analyse the long-term benefits early interventional therapy may have upon a child's later development. Initial results have revealed positive and promising effects for both patients and parents(44, 45). Studies surrounding these topics are difficult to carry out without a selection bias, because predominantly patients with more pronounced DDs and NDs require early supportive therapy. It has been argued that all CHD patients should receive prophylactic early supportive treatment to minimize the likelihood of any later complications(16). However, there are not enough studies to support such an extensive proposal and the financial strain on the health sector makes universal prophylactic treatment unfeasible.

4.6. Impact of Psychological and Behavioural Disorders

A high percentage of patients (33.3%) reported the diagnosis of a psychological, behavioural or learning disorder. Diagnosis rates differed significantly between the different severity subgroups. Patients with a diagnosed disorder more frequently attended academically lower ranked secondary schools and graduated with lower ranked secondary school degrees. Previous studies have reported similar high prevalence rates of psychological, behavioural and learning disorders within the CHD community but very few studies have analysed how said disorders affect patients in their daily lives and at school (77, 78, 94-97, 99).

The diagnosis, the surrounding therapy, extended periods of inpatient treatment and the ensuing limitations of a CHD can be very stressful and can have an imprinting effect on a child and may contribute to the high disorder prevalence in the CHD community. Severe CHD patients usually receive longer and more invasive inpatient treatment, which explains the higher disorder prevalence within this severity subgroup. For an extended period of their childhoods, patients are unable to experience a normal upbringing and are very limited in their possibilities and social interactions. This upbringing may have a negative effect on CHD patients' psychological development and may contribute to the high prevalence of diagnosed disorders among long-term CHD patients (95, 99). The high prevalence of DDs and NDs in the CHD patient community may negatively influence a CHD patient's psychological and behavioural development. Social competence and interaction and emotional awareness can be reduced in CHD patients(77, 94-96, 99). This may make it harder for CHD patients to form meaningful friendships putting them at risk for psychological or behavioural disorders. In addition, factors such as delayed brain maturation, lower cortical development, unspecific white matter lesions and lower cerebral blood flow to a degree likely contribute to the high prevalence of diagnosed disorders among the CHD patient community(57-62).

On the other hand, the high prevalence of diagnosed disorders may be due to the increased awareness among treating physicians. Treating physicians may be more inclined to diagnose said disorders among CHD patients than in the general population. In addition, follow-up examinations in regular intervals may make it easier to diagnose disorders.

The high prevalence of psychological disorders within the CHD population in our study emphasizes the need for the development and implementation of standardized psychological evaluation tests. Future studies should aim to identify internal and external risk factors to be better able to plan interventional therapies aimed at preventing psychological and behavioural disorders. Inpatient

treatment duration has been identified as such a risk factor and physicians should aim to shorten hospitalization periods whenever medically possible and responsible(78, 82, 83). Innate risk factors such as the severity of the CHD, delayed intrauterine brain maturation and the required cardiac surgery cannot be influenced. Only by identifying external risk factors can treating physicians hope to decrease the prevalence of psychological and behavioural disorders in the CHD patient community. Preliminary studies have shown that early supportive interventions may significantly reduce long-term complications in the psychological as well as the behavioural field for both patients and their families(44, 45).

4.7. Impact of CHDs on School Careers

The main goal of this study was to analyse the school careers of CHD patients according to the severity of their CHD and to compare our findings to the school careers of students from the general population. To this day, only a limited number of studies have taken a closer look at the school careers and secondary school education levels of CHD patients. In the past, studies have predominantly focused on the prevalence and severity of possible DDs and NDs in CHD patients during infancy and childhood. However, due to the age shift in the CHD population, long-term effects of NDS and DDs on a patient's education are now of increasing interest(5). Adult CHD patients now outnumber child CHD patients, which has led to questions surrounding their academic and professional careers and later QoL (5). NDs and DDs are analysed and verified using standardized developmental tests during infancy and childhood, however, their negative impact on a patient's school career and QoL manifests itself at a later age (71, 91).

Our initial results are promising and the bulk of CHD patients experienced average to above-average school careers compared to students from the general population. The majority of CHD patients enrolled at normal elementary schools at a school-typical age, attended academically challenging secondary schools and graduated with high ranked secondary school degrees. Compared to the general population in the school year 2016/2017 CHD patients on average were younger at the age of enrolment, attended academically similarly challenging secondary schools and depending on the severity of their CHD graduated with academically higher ranked secondary school degrees.

However, certain aspects of CHD patients' school careers were below average. CHD patients frequently repeated one or more school years, and often required additional after-school tutoring.

While CHD patients on average enjoyed normal school careers, increased CHD severity had a negative impact on patients' school and academic achievements within our patient cohort.
Significant differences were observed between the different severity subgroups in the following areas: age and school form at enrolment, secondary school form attended, grade repetition rates, after-school tutoring required and secondary school graduation rates.

In Germany, elementary school enrolment is considered normal up to the age of seven, meaning that the vast majority of patients (98.3%) were enrolled in elementary school at a school-typical age. CHD patients were more likely to be enrolled at a younger age than children from the general population were. In the school year 2016/2017 0.3% of students from the general population were enrolled by the age of five in comparison to 4.7% of CHD patients in our study. 74.6% of CHD patients were enrolled at the age of six or younger compared to only 64% of the general population.
Age at enrolment differed between the different severity subgroups. Though more frequently enrolled at school at a later age than mild CHD patients, severe CHD patients were still enrolled in elementary school at age six or younger at a similar rate compared to the general population in 2016/2017 (68.2% vs. 64% respectively). Mild CHD patients were more frequently enrolled at the age of six or younger (83%) than students from the general population (64%).

While the predominant amount of CHD patients enrolled in a normal elementary school, moderate and severe CHDs increased the likelihood of requiring special education support. Alternative school forms were more popular among CHD patients in our study than among students from the general population, especially in the moderate and severe CHD subgroups.
The extent of the differences in secondary school form attendance and graduation between CHD patients in our study and the general population varied greatly depending on the severity of the CHD in question. In the school year 2016/2017, modern secondary schools were slightly more popular in the general population than in our CHD patient collective (7.5% vs. 6.3% of CHD patients). In contrast, students from the general population less frequently attended intermediate secondary schools than CHD patients (15.8% vs. 22.5% of CHD patients).
From the general population 9.8% of students attended a multi-tiered secondary school (vs. 4.9% of CHD patients) and 13.5% attended a comprehensive school (vs. 9.2% of CHD patients) in the 2016/2017 school year. In the school year 2016/2017 upper level secondary schools were the most

popular school form in the general population with 43.8% of students (vs. 42.6% of CHD patients) attending this school form. Mild CHD patients attended upper level secondary schools slightly more frequently than students from the general population (50.9% vs. 43.8%) while moderate CHD patients attended with a similar frequency (43.1% vs. 43.8%). Severe CHD patients attended upper level secondary schools less often than students from the general population did (35.1% vs. 43.8%).

While mild and moderate CHD patients attended upper level secondary schools more often or with a similar frequency compared to the general population, severe CHD patients' school careers were negatively impacted by their underlying CHD. Surprisingly, mild CHDs appeared to have a positive influence on patients' school careers, increasing the likelihood of attending academically more challenging school forms.

In the school year 2016/2017 a greater percentage of students from the general population graduated from secondary school with a modern (16%) or with an intermediate secondary school diploma (43%) compared to CHD patients (8.3% / 23.1%) in our study. In contrast, 58% of CHD patients graduated with a degree permitting university admission compared to only 35.1% of students from the general population. The difference between CHD patients (58%, of which 45.7% with "Abitur" and 12.3% with polytechnical degree)) and the general population (52% of which 41% with "Abitur" and 11% with polytechnical degree) with higher education entrance qualifications was smaller when taking into account the high percentage of students that attained higher ranking secondary school diplomas during their post-secondary school degrees.

Mild and moderate CHD patients graduated with higher education entrance qualifications more frequently than students from the general population did (67.7% and 60.7% respectively vs. 51%). While moderate and severe CHDs were a risk factor for lower ranked secondary school degrees within our CHD patient cohort, only severe CHD patients were less likely to graduate with higher education entrance qualifications than students from the general population were (48.2% vs. 51%).

Severe CHD patients frequently had special educational needs, attended lower ranked secondary schools, repeated a school year and graduated with lower ranked secondary school diplomas.

In contrast, mild CHDs appear to have a beneficial effect on patients' school careers. Compared to the general population mild CHD patients were far more likely to enrol in school at a younger age, attend academically more challenging secondary schools and graduate with academically higher ranked secondary school diplomas

Though promising, our initial results must be interpreted with caution and further studies are needed to validate any findings.

4.7.1. Study Comparison

To date there are only a limited number of studies that analyse the education levels and school careers of CHD patients in adolescence and adulthood. These studies have come to a broad range of contradictory conclusions based on the study format, location and parameters assessed(72, 78, 80, 90, 97, 100-104). Certain studies have reported results that coincide with our own and have observed above average school careers in the CHD population and in other chronically ill patient groups.

Former childhood leukaemia patients and childhood brain tumour survivors frequently graduated with academically challenging secondary school degrees and attained high levels of education(112, 113). Schaefer et al. analysed the school performance and school degrees of Swiss CHD patients between the age of 17 and 19. CHD patients experienced similar to slightly better school careers, compared to the general Swiss population, though patients with severe CHDs received worse grades at school (100). Switzerland like Germany has a multi-tiered school system allowing for a high level of comparability between our studies. Nieminen et al. reported similar education levels and higher employment rates in Finnish CHD patients compared to the Finnish population (101). Bygstad et al. reported similar education levels in Danish CHD patients with Tetralogy of Fallot though unemployment was reported to be higher and more patients received social benefits compared to the general Danish population (102). These European studies support our observations, though none reported the same potential positive influence of mild CHDs on a patient's school and professional career. Pfitzer et al. observed CHD patients to have significantly higher education levels and to more often be employed in above average paying jobs than the general population (104). Like in our study, mild CHDs had a positive influence on the final degree attained. The fact that CHD patients had higher paying jobs was attributed to the fact that they had higher final education levels permitting a greater variety of career options. However, Pfitzer et al. recruited patients through the NRCHD database so the patient collective may overlap with our own to an extent(104).

Other studies have come to less positive conclusions that contradict our findings. A Turkish study noted that military aged male CHD patients were significantly less likely to attend and graduate from university, regardless of the severity of their underlying CHD (90). In this study, the only protective factor analysed was an older age at initial surgery. Olsen et al. observed significantly worse academic

performances in Danish CHD survivors compared to the general population (103). In other cases, academic achievements have been within the normal limits but below expectations (84). When asked to assess their school performance CHD patients offered poor self-evaluations and reported low school QoL(43, 72). Studies have reported lower levels of school competence and performance in CHD patient cohorts (72, 84). Poor academic performance has been attributed to the high prevalence of DDs and NDs in the CHD patient community.

4.7.2. Result Interpretation

Numerous aspects have to be taken into consideration when interpreting our results.

Chronically ill children may mature at a younger age due to being confronted with serious health issues early in their lives. A higher level of maturity at school enrolment may make students more focused and more ambitious, which in turn may translate to better overall academic achievements. CHD patients are also frequently limited in their ability to participate in physical education (P.E.) classes and are restricted in their ability to participate in school sports or after-school sports teams. In turn, CHD patients may be forced to pursue hobbies of a more academic nature (49). This in turn may help CHD patients perform better at school and explain their above average school careers. Parents of chronically sick children and of CHD patients tend to be more involved in their children's lives on a day-to-day basis and have been observed to exhibit more involved parenting styles(86, 87). CHD patients may receive more attention and support from their parents and families. More involved parents are likely to notice academic or social difficulties and intervene at an earlier stage. The high reported prevalence of after-school tutoring in our study supports this assumption. Parents may notice their children struggling with certain subjects and acquire after-school tutors to help them overcome their academic difficulties at school. Too intrusive parents can be harmful and can increase dependency and inhibit a child's development. However, parents more involved and vested in their children's upbringing and education are nothing negative and can contribute to better academic achievements and above average school careers.

CHD patients should receive follow-up examinations for an extended period of time after the initial diagnosis and treatment(48). During this time period, patients are closely observed and examined for possible DDs and NDs. Prolonged longitudinal contact to a specialized paediatrician enables the early diagnosis of any learning, developmental, neurological, psychological or behavioural disorders. The high rate of early interventional therapy received by CHD patients in our study supports this theory.

Early interventional therapy can help CHD patients overcome DDs and NDs and can help them lead independent and healthy lives(44, 45). Perceived shortcomings may be just as frequent in the general population but the lack of longitudinal follow-up examinations may decrease the likelihood of a diagnosis.
To summarize, a more intense parent-patient relationship, greater maturity at a young age, more hobbies of an academic nature, more after-school tutoring and more early interventional therapy were most likely responsible for the above average school careers of CHD patients in our study.

However, the high prevalence of psychological and behavioural disorders as well as high grade repetition rates emphasized the difficulties that CHD patients are confronted with at school. The exact reasons for having to repeat a school year were not elicited in our study. CHD patients, especially severe CHD patients, frequently received inpatient treatment for a period of > 6 months. Poor attendance may make it necessary for students to repeat the school year. This would have been more of a reflection of their lower attendance than of their intelligence or academic performance.
CHD patients were frequently diagnosed with one or more psychological, behavioural or learning disorder (33.3%). Especially the moderate (34.5%) and severe (41.6%) CHD subgroups were at risk for said disorders. Like in our study, Shillingford et al. reported a high prevalence of attention deficit and hyperactivity disorders among CHD patients that likely contributed to a high rate of school year repetition among CHD patients(97). However, the reported overall academic achievements of CHD patients were not negatively impacted and according to teacher ratings, more than half of these students still performed average to above average at school(97). In our study, a diagnosed psychological, behavioural or learning disorder significantly increased the likelihood of having to repeat a school year and negatively affected the secondary school form attended and the rate at which students graduated with “Abitur”. Patients with a diagnosed disorder may have exhibited disruptive behaviour making it necessary for them to repeat a school year.

In our study, the significant differences between the different CHD severity subgroups in school form and age at enrolment, secondary school form attended and secondary school degree upon graduation can be attributed to the high DD and ND prevalence, inpatient treatment duration, presumed lower brain maturity and high psychological disorder prevalence within the more severe patient subgroups (38, 57-60, 75, 76, 80, 107). Said disorders are more prevalent in more severe and cyanotic CHD

subgroups and are likely to have negatively affected the school careers of patients predominantly within our moderate and severe patient subgroups. Severe CHD patients less frequently graduated with higher education entrance qualifications than the general population. In other aspects however severe CHD patients experienced average school careers. Therefore, it appears that a more intense parent-patient relationship, greater maturity at a young age, more hobbies of an academic nature, more after-school tutoring and more early interventional therapy can counteract the negative impact of a CHD to an extent.

As mentioned above, mild CHDs had a positive influence on patients' school careers and mild CHD patients more frequently attended academically higher ranked secondary schools and were more likely to graduate with the general university entrance qualifications than other severity subgroups and the general population. Like severe CHD patients, mild CHD patients may experience more protective and involved parents, long follow-up examination periods and high rates of additional tutoring. However, DDs, NDs and psychological and learning disorders are far less prevalent among mild CHD patients than among moderate or severe CHD patients (79, 82, 83). Mild CHDs rarely have an impact on intrauterine brain maturation and development(58-60). This patient subgroup likely experiences the "benefits" that come with having a CHD, while less frequently suffering from NDs and DDs.
The contradictory results in European studies highlight the need for additional large longitudinal studies to better analyse the educational and professional careers of CHD patients.

5. Limitations

There was a significant overrepresentation of CHDs classified as moderate (32.2%) and severe (36.7%) in our study cohort. In part, this can be explained by the pre-existing overrepresentation of moderate and severe CHDs in the database of the NRCHD, due to its clinical nature(10). The form and topic of our study may have reinforced this selection bias. The prevalence of the individual severity subgroups was within an acceptable range and it can be argued that a large number of patients with moderate and severe CHDs benefited the study, as numerous studies have observed DDs and NDs to be more prevalent in the moderate and severe CHD patient subgroup.

Another limitation was the low corrected final participation rate of 11.8%. The low response rate is in part due to the timing of our survey (German summer school holidays) and to the nature of the questionnaire with its broadly defined inclusion criteria and large amount of questions. No non-responder analysis took place and therefore an analytical comparison of both groups was not possible. Visser et al.(114) has argued that response rates of 20% can at times be more accurate than response rates of 70%. Our final response rate of 11.8% was deemed acceptable due to the large patient cohort. However, there was an increased possibility of a selection bias. Participants too strongly handicapped by their CHD to attend school may not have participated in this study, exaggerating our positive results. In past studies, more successful and more highly educated CHD patients and their families may have been more inclined to participate and this may have led to a selection bias (53, 104). Our findings should be interpreted with caution and future studies are needed before results can be generalized. Cause and effect analyses were not possible due to the cross-sectional nature of our study. The place of residence was not determined so it remains unknown how many patients from the individual states participated. In addition, we did not differentiate between urban and industrial regions or take into account CHD patients' SES. In addition, prenatal detection rates may differ between urban and industrial regions. Parental education levels and professions play a large role in children's upbringings and strongly influence their school and career choices(88).

Our findings were compared to the results published by the German Federal Statistics Office "Schulen auf einen Blick 2018"(108). This comparison must be treated with caution due to the different form of data acquisition between the census data and our study data. The census data analysed the school year 2016/2017, while our study analysed a school period of approximately 20 years. Our data shows cumulative prevalence in contrast to the point prevalence of the census data of the school year 2016/2017. All comparisons are of an exemplary nature and show indicative tendencies between CHD

patients and the general population. The trend towards higher education in the past decades was not taken into consideration during our comparison(108). However, this would work in our favour and only increase the significance of our findings.

6. Conclusion

The main aim of our study was to analyse and compare the school careers of CHD patients to the general population and between the individual severity subgroups. The aim was to identify CHDs as independent risk factors for below average school careers. However, the majority of participants reported that CHD patients experienced average to above average school careers compared to the general population, regardless of the severity of the underlying CHD. CHD patients were more likely to enrol in school at a younger age, and depending on the severity of the CHD, attend and graduate from academically more challenging secondary schools. Mild CHDs appear to have a beneficial influence on patients' school careers concerning their age at enrolment, secondary school form attended and degree attained upon graduation. These initial results are very promising and can help to alleviate parents' fears concerning their child's development, school career and later QoL.

However, not all aspects of CHD patient's school careers were above average and patients were often faced with difficulties at school reflected in the increased likelihood to require special assistance at enrolment, to receive additional after-school tutoring, to repeat a school year and to be diagnosed with a psychological or behavioural disorder.

Within our study cohort, increased CHD severity had a negative impact on CHD patients' school careers and academic achievements. Severe CHD patients performed worse than mild and moderate CHD patients in all aspects of their school careers and on average graduated with lower ranked secondary school degrees than the general population. These results highlight the role CHD severity has on a patient's upbringing, school career, and later QoL. Inpatient treatment duration and psychological, behavioural and learning disorders were identified as risk factors for below average school careers. Long-term longitudinal studies are required to identify additional external risk factors that may have an impact on a patient's school career. In time, effective interventional therapies able to minimize the negative effect a CHD has on a patient have to be developed.

Prenatal diagnosis rates have improved over the past 20 years, but remain behind todays technological possibilities. Prenatal detection rates need to continue to improve and measures need to be implemented to better detect high risk pregnancies. Our study highlighted the need for patients to be more strongly involved in decision-making processes at a young age to prevent loss at follow-up and misconceptions concerning limitations surrounding their CHDs.

The long-term goal is to successfully identify influenceable risk factors and develop early interventional therapies to ensure that CHD survivors can experience a normal upbringing and school career regardless of the severity of the CHD.

7. References

1. Mitchell SC, Korones SB, Berendes HW. Congenital heart disease in 56,109 births. Incidence and natural history. Circulation. 1971;43(3):323-32.
2. Dolk H, Loane M, Garne E, European Surveillance of Congenital Anomalies Working G. Congenital heart defects in Europe: prevalence and perinatal mortality, 2000 to 2005. Circulation. 2011;123(8):841-9.
3. Lindinger A, Schwedler G, Hense HW. Prevalence of congenital heart defects in newborns in Germany: Results of the first registration year of the PAN Study (July 2006 to June 2007). Klin Padiatr. 2010;222(5):321-6.
4. Liu Y, Chen S, Zuhlke L, Black GC, Choy MK, Li N, Keavney BD. Global birth prevalence of congenital heart defects 1970-2017: updated systematic review and meta-analysis of 260 studies. Int J Epidemiol. 2019.
5. Marelli AJ, Ionescu-Ittu R, Mackie AS, Guo L, Dendukuri N, Kaouache M. Lifetime prevalence of congenital heart disease in the general population from 2000 to 2010. Circulation. 2014;130(9):749-56.
6. Marelli AJ, Mackie AS, Ionescu-Ittu R, Rahme E, Pilote L. Congenital heart disease in the general population: changing prevalence and age distribution. Circulation. 2007;115(2):163-72.
7. Schwedler G, Lindinger A, Lange PE, Sax U, Olchvary J, Peters B, Bauer U, Hense HW. Frequency and spectrum of congenital heart defects among live births in Germany : a study of the Competence Network for Congenital Heart Defects. Clin Res Cardiol. 2011;100(12):1111-7.
8. van der Linde D, Konings EE, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJ, Roos-Hesselink JW. Birth prevalence of congenital heart disease worldwide: a systematic review and meta-analysis. J Am Coll Cardiol. 2011;58(21):2241-7.
9. Hoffman JI, Kaplan S. The incidence of congenital heart disease. J Am Coll Cardiol. 2002;39(12):1890-900.
10. Helm PC, Koerten MA, Abdul-Khaliq H, Baumgartner H, Kececioglu D, Bauer UM. Representativeness of the German National Register for Congenital Heart Defects: a clinically oriented analysis. Cardiol Young. 2016;26(5):921-6.
11. Warnes CA, Liberthson R, Danielson GK, Dore A, Harris L, Hoffman JI, Somerville J, Williams RG, Webb GD. Task force 1: the changing profile of congenital heart disease in adult life. J Am Coll Cardiol. 2001;37(5):1170-5.
12. Khoshnood B, De Vigan C, Vodovar V, Goujard J, Lhomme A, Bonnet D, Goffinet F. Trends in prenatal diagnosis, pregnancy termination, and perinatal mortality of newborns with congenital heart disease in France, 1983-2000: a population-based evaluation. Pediatrics. 2005;115(1):95-101.
13. Reid GJ, Webb GD, Barzel M, McCrindle BW, Irvine MJ, Siu SC. Estimates of life expectancy by adolescents and young adults with congenital heart disease. J Am Coll Cardiol. 2006;48(2):349-55.
14. Kendall L, Lewin RJ, Parsons JM, Veldtman GR, Quirk J, Hardman GE. Factors associated with self-perceived state of health in adolescents with congenital cardiac disease attending paediatric cardiologic clinics. Cardiol Young. 2001;11(4):431-8.
15. Latal B, Helfricht S, Fischer JE, Bauersfeld U, Landolt MA. Psychological adjustment and quality of life in children and adolescents following open-heart surgery for congenital heart disease: a systematic review. BMC Pediatr. 2009;9:6.

16. Marino BS, Lipkin PH, Newburger JW, Peacock G, Gerdes M, Gaynor JW, Mussatto KA, Uzark K, Goldberg CS, Johnson WH, Jr., Li J, Smith SE, Bellinger DC, Mahle WT, American Heart Association Congenital Heart Defects Committee CoCDitYCoCN, Stroke C. Neurodevelopmental outcomes in children with congenital heart disease: evaluation and management: a scientific statement from the American Heart Association. Circulation. 2012;126(9):1143-72.
17. Mussatto KA, Hoffmann RG, Hoffman GM, Tweddell JS, Bear L, Cao Y, Brosig C. Risk and prevalence of developmental delay in young children with congenital heart disease. Pediatrics. 2014;133(3):e570-7.
18. Garne E. Atrial and ventricular septal defects - epidemiology and spontaneous closure. J Matern Fetal Neonatal Med. 2006;19(5):271-6.
19. Tweddell JS, Hoffman GM, Mussatto KA, Fedderly RT, Berger S, Jaquiss RD, Ghanayem NS, Frisbee SJ, Litwin SB. Improved survival of patients undergoing palliation of hypoplastic left heart syndrome: lessons learned from 115 consecutive patients. Circulation. 2002;106(12 Suppl 1):I82-9.
20. Eckersley L, Sadler L, Parry E, Finucane K, Gentles TL. Timing of diagnosis affects mortality in critical congenital heart disease. Arch Dis Child. 2016;101(6):516-20.
21. Ailes EC, Gilboa SM, Riehle-Colarusso T, Johnson CY, Hobbs CA, Correa A, Honein MA, National Birth Defects Prevention S. Prenatal diagnosis of nonsyndromic congenital heart defects. Prenat Diagn. 2014;34(3):214-22.
22. Lytzen R, Vejlstrup N, Bjerre J, Petersen OB, Leenskjold S, Dodd JK, Jorgensen FS, Sondergaard L. Mortality and morbidity of major congenital heart disease related to general prenatal screening for malformations. Int J Cardiol. 2019;290:93-9.
23. Marek J, Tomek V, Skovranek J, Povysilova V, Samanek M. Prenatal ultrasound screening of congenital heart disease in an unselected national population: a 21-year experience. Heart. 2011;97(2):124-30.
24. Rossier MC, Mivelaz Y, Addor MC, Sekarski N, Meijboom EJ, Vial Y. Evaluation of prenatal diagnosis of congenital heart disease in a regional controlled case study. Swiss Med Wkly. 2014;144:w14068.
25. Vincenti M, Guillaumont S, Clarivet B, Macioce V, Mura T, Boulot P, Cambonie G, Amedro P. Prognosis of severe congenital heart diseases: Do we overestimate the impact of prenatal diagnosis? Arch Cardiovasc Dis. 2019;112(4):261-9.
26. van Velzen CL, Ket JCF, van de Ven PM, Blom NA, Haak MC. Systematic review and meta-analysis of the performance of second-trimester screening for prenatal detection of congenital heart defects. Int J Gynaecol Obstet. 2018;140(2):137-45.
27. Khoshnood B, Lelong N, Houyel L, Thieulin AC, Jouannic JM, Magnier S, Delezoide AL, Magny JF, Rambaud C, Bonnet D, Goffinet F, Group ES. Prevalence, timing of diagnosis and mortality of newborns with congenital heart defects: a population-based study. Heart. 2012;98(22):1667-73.
28. Pinto NM, Keenan HT, Minich LL, Puchalski MD, Heywood M, Botto LD. Barriers to prenatal detection of congenital heart disease: a population-based study. Ultrasound Obstet Gynecol. 2012;40(4):418-25.
29. Quartermain MD, Pasquali SK, Hill KD, Goldberg DJ, Huhta JC, Jacobs JP, Jacobs ML, Kim S, Ungerleider RM. Variation in Prenatal Diagnosis of Congenital Heart Disease in Infants. Pediatrics. 2015;136(2):e378-85.

30. Comas Gabriel C, Galindo A, Martinez JM, Carrera JM, Gutierrez-Larraya F, de la Fuente P, Puerto B, Borrell A. Early prenatal diagnosis of major cardiac anomalies in a high-risk population. Prenat Diagn. 2002;22(7):586-93.
31. Landis BJ, Levey A, Levasseur SM, Glickstein JS, Kleinman CS, Simpson LL, Williams IA. Prenatal diagnosis of congenital heart disease and birth outcomes. Pediatr Cardiol. 2013;34(3):597-605.
32. Tworetzky W, McElhinney DB, Reddy VM, Brook MM, Hanley FL, Silverman NH. Improved surgical outcome after fetal diagnosis of hypoplastic left heart syndrome. Circulation. 2001;103(9):1269-73.
33. Franklin O, Burch M, Manning N, Sleeman K, Gould S, Archer N. Prenatal diagnosis of coarctation of the aorta improves survival and reduces morbidity. Heart. 2002;87(1):67-9.
34. Fuchs IB, Muller H, Abdul-Khaliq H, Harder T, Dudenhausen JW, Henrich W. Immediate and long-term outcomes in children with prenatal diagnosis of selected isolated congenital heart defects. Ultrasound Obstet Gynecol. 2007;29(1):38-43.
35. Calderon J, Angeard N, Moutier S, Plumet MH, Jambaque I, Bonnet D. Impact of prenatal diagnosis on neurocognitive outcomes in children with transposition of the great arteries. J Pediatr. 2012;161(1):94-8 e1.
36. Oster ME, Kim CH, Kusano AS, Cragan JD, Dressler P, Hales AR, Mahle WT, Correa A. A population-based study of the association of prenatal diagnosis with survival rate for infants with congenital heart defects. Am J Cardiol. 2014;113(6):1036-40.
37. Tegnander E, Williams W, Johansen OJ, Blaas HG, Eik-Nes SH. Prenatal detection of heart defects in a non-selected population of 30,149 fetuses--detection rates and outcome. Ultrasound Obstet Gynecol. 2006;27(3):252-65.
38. Brosig CL, Bear L, Allen S, Hoffmann RG, Pan A, Frommelt M, Mussatto KA. Preschool Neurodevelopmental Outcomes in Children with Congenital Heart Disease. J Pediatr. 2017;183:80-6 e1.
39. Kipps AK, Feuille C, Azakie A, Hoffman JI, Tabbutt S, Brook MM, Moon-Grady AJ. Prenatal diagnosis of hypoplastic left heart syndrome in current era. Am J Cardiol. 2011;108(3):421-7.
40. Levey A, Glickstein JS, Kleinman CS, Levasseur SM, Chen J, Gersony WM, Williams IA. The impact of prenatal diagnosis of complex congenital heart disease on neonatal outcomes. Pediatr Cardiol. 2010;31(5):587-97.
41. Pinto NM, Nelson R, Botto L, Puchalski MD, Krikov S, Kim J, Waitzman NJ. Costs, mortality, and hospital usage in relation to prenatal diagnosis in d-transposition of the great arteries. Birth Defects Res. 2017;109(4):262-70.
42. Rychik J, Donaghue DD, Levy S, Fajardo C, Combs J, Zhang X, Szwast A, Diamond GS. Maternal psychological stress after prenatal diagnosis of congenital heart disease. J Pediatr. 2013;162(2):302-7 e1.
43. Uzark K, Jones K, Slusher J, Limbers CA, Burwinkle TM, Varni JW. Quality of life in children with heart disease as perceived by children and parents. Pediatrics. 2008;121(5):e1060-7.
44. McCusker CG, Doherty NN, Molloy B, Rooney N, Mulholland C, Sands A, Craig B, Stewart M, Casey F. A controlled trial of early interventions to promote maternal adjustment and development in infants born with severe congenital heart disease. Child Care Health Dev. 2010;36(1):110-7.
45. McCusker CG, Doherty NN, Molloy B, Rooney N, Mulholland C, Sands A, Craig B, Stewart M, Casey F. A randomized controlled trial of interventions to promote adjustment in children with

congenital heart disease entering school and their families. J Pediatr Psychol. 2012;37(10):1089-103.
46. Mussatto KA, Hollenbeck-Pringle D, Trachtenberg F, Sood E, Sananes R, Pike NA, Lambert LM, Mahle WT, Goldberg DJ, Goldberg CS, Dunbar-Masterson C, Otto M, Marino BS, Bartle BH, Williams IA, Jacobs JP, Zyblewski SC, Pemberton VL. Utilisation of early intervention services in young children with hypoplastic left heart syndrome. Cardiol Young. 2018;28(1):126-33.
47. Helm PC, Bauer UMM, Abdul-Khaliq H, Baumgartner H, Kramer HH, Schlensak C, Pickardt T, Kahlert AK, Hitz MP. Patients with congenital heart defect and their families support genetic heart research. Congenit Heart Dis. 2018;13(5):685-9.
48. Mackie AS, Ionescu-Ittu R, Therrien J, Pilote L, Abrahamowicz M, Marelli AJ. Children and adults with congenital heart disease lost to follow-up: who and when? Circulation. 2009;120(4):302-9.
49. Werner O, Abassi H, Lavastre K, Guillaumont S, Picot MC, Serrand C, Dulac Y, Souletie N, Acar P, Bredy C, Amedro P. Factors influencing the participation of adolescents and young adults with a congenital heart disease in a transition education program: A prospective multicentre controlled study. Patient Educ Couns. 2019.
50. Helm PC, Kempert S, Korten MA, Lesch W, Specht K, Bauer UMM. Congenital heart disease patients' and parents' perception of disease-specific knowledge: Health and impairments in everyday life. Congenit Heart Dis. 2018;13(3):377-83.
51. Lesch W, Specht K, Lux A, Frey M, Utens E, Bauer U. Disease-specific knowledge and information preferences of young patients with congenital heart disease. Cardiol Young. 2014;24(2):321-30.
52. Bauer UMM, Helm PC, Diller GP, Asfour B, Schlensak C, Schmitt K, Ewert P, Tutarel O. Are adults with congenital heart disease informed about their risk for infective endocarditis and treated in accordance to current guidelines? Int J Cardiol. 2017;245:105-8.
53. Helm PC, Korten MA, Abdul-Khaliq H, Asfour B, Baumgartner H, Breithardt G, Kececioglu D, Schlensak C, Diller GP, Bauer UM. Three parties, one direction: Research priorities in adults with congenital heart disease. What do professionals, patients and relatives want to know? Int J Cardiol. 2016;207:220-9.
54. Kaemmerer M, Vigl M, Seifert-Klauss V, Nagdyman N, Bauer U, Schneider KT, Kaemmerer H. Counseling reproductive health issues in women with congenital heart disease. Clin Res Cardiol. 2012;101(11):901-7.
55. Warnes CA, Williams RG, Bashore TM, Child JS, Connolly HM, Dearani JA, Del Nido P, Fasules JW, Graham TP, Jr., Hijazi ZM, Hunt SA, King ME, Landzberg MJ, Miner PD, Radford MJ, Walsh EP, Webb GD. ACC/AHA 2008 guidelines for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Develop Guidelines on the Management of Adults With Congenital Heart Disease). Developed in Collaboration With the American Society of Echocardiography, Heart Rhythm Society, International Society for Adult Congenital Heart Disease, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. J Am Coll Cardiol. 2008;52(23):e143-e263.
56. Helm PC, Sticker EJ, Keuchen R, Koerten MA, Diller GP, Tutarel O, Bauer UMM. Is having a job a protective factor? Employment status and state of medical care as subjectively perceived by adults with CHD in Germany. Cardiol Young. 2017;27(6):1110-7.

57. Owen M, Shevell M, Majnemer A, Limperopoulos C. Abnormal brain structure and function in newborns with complex congenital heart defects before open heart surgery: a review of the evidence. J Child Neurol. 2011;26(6):743-55.
58. Miller SP, McQuillen PS, Hamrick S, Xu D, Glidden DV, Charlton N, Karl T, Azakie A, Ferriero DM, Barkovich AJ, Vigneron DB. Abnormal brain development in newborns with congenital heart disease. N Engl J Med. 2007;357(19):1928-38.
59. Limperopoulos C, Tworetzky W, McElhinney DB, Newburger JW, Brown DW, Robertson RL, Jr., Guizard N, McGrath E, Geva J, Annese D, Dunbar-Masterson C, Trainor B, Laussen PC, du Plessis AJ. Brain volume and metabolism in fetuses with congenital heart disease: evaluation with quantitative magnetic resonance imaging and spectroscopy. Circulation. 2010;121(1):26-33.
60. Licht DJ, Shera DM, Clancy RR, Wernovsky G, Montenegro LM, Nicolson SC, Zimmerman RA, Spray TL, Gaynor JW, Vossough A. Brain maturation is delayed in infants with complex congenital heart defects. J Thorac Cardiovasc Surg. 2009;137(3):529-36; discussion 36-7.
61. von Rhein M, Buchmann A, Hagmann C, Huber R, Klaver P, Knirsch W, Latal B. Brain volumes predict neurodevelopment in adolescents after surgery for congenital heart disease. Brain. 2014;137(Pt 1):268-76.
62. Ortinau C, Beca J, Lambeth J, Ferdman B, Alexopoulos D, Shimony JS, Wallendorf M, Neil J, Inder T. Regional alterations in cerebral growth exist preoperatively in infants with congenital heart disease. J Thorac Cardiovasc Surg. 2012;143(6):1264-70.
63. Beca J, Gunn JK, Coleman L, Hope A, Reed PW, Hunt RW, Finucane K, Brizard C, Dance B, Shekerdemian LS. New white matter brain injury after infant heart surgery is associated with diagnostic group and the use of circulatory arrest. Circulation. 2013;127(9):971-9.
64. Heinrichs AK, Holschen A, Krings T, Messmer BJ, Schnitker R, Minkenberg R, Hovels-Gurich HH. Neurologic and psycho-intellectual outcome related to structural brain imaging in adolescents and young adults after neonatal arterial switch operation for transposition of the great arteries. J Thorac Cardiovasc Surg. 2014;148(5):2190-9.
65. Visootsak J, Mahle WT, Kirshbom PM, Huddleston L, Caron-Besch M, Ransom A, Sherman SL. Neurodevelopmental outcomes in children with Down syndrome and congenital heart defects. Am J Med Genet A. 2011;155A(11):2688-91.
66. Franceschini P, Guala A, Vardeu MP, Signorile F, Franceschini D, Mastroiacovo P, Gianotti A, Livini E, Lalatta F, Selicorni A, Andria G, Scarano G, Della Monica M, Rizzo R, Zelante L, Stabile M, Gabrielli O, Neri G. The Williams syndrome: an Italian collaborative study. Minerva Pediatr. 1996;48(10):421-8.
67. Ko JM. Genetic Syndromes associated with Congenital Heart Disease. Korean Circ J. 2015;45(5):357-61.
68. Carey AS, Liang L, Edwards J, Brandt T, Mei H, Sharp AJ, Hsu DT, Newburger JW, Ohye RG, Chung WK, Russell MW, Rosenfeld JA, Shaffer LG, Parides MK, Edelmann L, Gelb BD. Effect of copy number variants on outcomes for infants with single ventricle heart defects. Circ Cardiovasc Genet. 2013;6(5):444-51.
69. Alton GY, Taghados S, Joffe AR, Robertson CM, Dinu I, Western Canadian Pediatric Therapies Follow-Up G. Prediction of preschool functional abilities after early complex cardiac surgery. Cardiol Young. 2015;25(4):655-62.

70. Cassidy AR, White MT, DeMaso DR, Newburger JW, Bellinger DC. Executive Function in Children and Adolescents with Critical Cyanotic Congenital Heart Disease. J Int Neuropsychol Soc. 2015;21(1):34-49.
71. Gaynor JW, Stopp C, Wypij D, Andropoulos DB, Atallah J, Atz AM, Beca J, Donofrio MT, Duncan K, Ghanayem NS, Goldberg CS, Hovels-Gurich H, Ichida F, Jacobs JP, Justo R, Latal B, Li JS, Mahle WT, McQuillen PS, Menon SC, Pemberton VL, Pike NA, Pizarro C, Shekerdemian LS, Synnes A, Williams I, Bellinger DC, Newburger JW, International Cardiac Collaborative on Neurodevelopment I. Neurodevelopmental outcomes after cardiac surgery in infancy. Pediatrics. 2015;135(5):816-25.
72. Gerstle M, Beebe DW, Drotar D, Cassedy A, Marino BS. Executive Functioning and School Performance among Pediatric Survivors of Complex Congenital Heart Disease. J Pediatr. 2016;173:154-9.
73. Tabbutt S, Gaynor JW, Newburger JW. Neurodevelopmental outcomes after congenital heart surgery and strategies for improvement. Curr Opin Cardiol. 2012;27(2):82-91.
74. Forbess JM, Visconti KJ, Bellinger DC, Howe RJ, Jonas RA. Neurodevelopmental outcomes after biventricular repair of congenital heart defects. J Thorac Cardiovasc Surg. 2002;123(4):631-9.
75. Latal B. Neurodevelopmental Outcomes of the Child with Congenital Heart Disease. Clin Perinatol. 2016;43(1):173-85.
76. Syrgani E, Petsios K. OC18 - Neurodevelopmental outcomes following congenital heart surgery. Nurs Child Young People. 2016;28(4):68.
77. Calderon J, Angeard N, Pinabiaux C, Bonnet D, Jambaque I. Facial expression recognition and emotion understanding in children after neonatal open-heart surgery for transposition of the great arteries. Dev Med Child Neurol. 2014;56(6):564-71.
78. von Rhein M, Dimitropoulos A, Valsangiacomo Buechel ER, Landolt MA, Latal B. Risk factors for neurodevelopmental impairments in school-age children after cardiac surgery with full-flow cardiopulmonary bypass. J Thorac Cardiovasc Surg. 2012;144(3):577-83.
79. Wotherspoon JM, Eagleson KJ, Gilmore L, Auld B, Hirst A, Johnson S, Stocker C, Heussler H, Justo RN. Neurodevelopmental and health-related quality-of-life outcomes in adolescence after surgery for congenital heart disease in infancy. Dev Med Child Neurol. 2019.
80. Bellinger DC, Wypij D, Rivkin MJ, DeMaso DR, Robertson RL, Jr., Dunbar-Masterson C, Rappaport LA, Wernovsky G, Jonas RA, Newburger JW. Adolescents with d-transposition of the great arteries corrected with the arterial switch procedure: neuropsychological assessment and structural brain imaging. Circulation. 2011;124(12):1361-9.
81. Miatton M, De Wolf D, Francois K, Thiery E, Vingerhoets G. Neuropsychological performance in school-aged children with surgically corrected congenital heart disease. J Pediatr. 2007;151(1):73-8, 8 e1.
82. Naef N, Liamlahi R, Beck I, Bernet V, Dave H, Knirsch W, Latal B. Neurodevelopmental Profiles of Children with Congenital Heart Disease at School Age. J Pediatr. 2017;188:75-81.
83. Majnemer A, Limperopoulos C, Shevell M, Rohlicek C, Rosenblatt B, Tchervenkov C. Developmental and functional outcomes at school entry in children with congenital heart defects. J Pediatr. 2008;153(1):55-60.
84. Bellinger DC, Wypij D, duPlessis AJ, Rappaport LA, Jonas RA, Wernovsky G, Newburger JW. Neurodevelopmental status at eight years in children with dextro-transposition of the great arteries: the Boston Circulatory Arrest Trial. J Thorac Cardiovasc Surg. 2003;126(5):1385-96.

85. Schaefer C, von Rhein M, Knirsch W, Huber R, Natalucci G, Caflisch J, Landolt MA, Latal B. Neurodevelopmental outcome, psychological adjustment, and quality of life in adolescents with congenital heart disease. Dev Med Child Neurol. 2013;55(12):1143-9.
86. Rempel GR, Harrison MJ. Safeguarding precarious survival: parenting children who have life-threatening heart disease. Qual Health Res. 2007;17(6):824-37.
87. Moola F, Fusco C, Kirsh JA. The perceptions of caregivers toward physical activity and health in youth with congenital heart disease. Qual Health Res. 2011;21(2):278-91.
88. Cassedy A, Drotar D, Ittenbach R, Hottinger S, Wray J, Wernovsky G, Newburger JW, Mahony L, Mussatto K, Cohen MI, Marino BS. The impact of socio-economic status on health related quality of life for children and adolescents with heart disease. Health Qual Life Outcomes. 2013;11:99.
89. Newburger JW, Wypij D, Bellinger DC, du Plessis AJ, Kuban KC, Rappaport LA, Almirall D, Wessel DL, Jonas RA, Wernovsky G. Length of stay after infant heart surgery is related to cognitive outcome at age 8 years. J Pediatr. 2003;143(1):67-73.
90. Ozcan EE, Kucuk A. Impact of severity of congenital heart diseases on university graduation rate among male patients. Turk Kardiyol Dern Ars. 2012;40(3):229-34.
91. Gaynor JW, Wernovsky G, Jarvik GP, Bernbaum J, Gerdes M, Zackai E, Nord AS, Clancy RR, Nicolson SC, Spray TL. Patient characteristics are important determinants of neurodevelopmental outcome at one year of age after neonatal and infant cardiac surgery. J Thorac Cardiovasc Surg. 2007;133(5):1344-53, 53 e1-3.
92. Werner O, El Louali F, Fouilloux V, Amedro P, Ovaert C. Parental anxiety before invasive cardiac procedure in children with congenital heart disease: Contributing factors and consequences. Congenit Heart Dis. 2019.
93. Association AP. American Psychological Association: Social Economic Status 05.08.2019 [Available from: https://www.apa.org/topics/socioeconomic-status/.
94. Freitas IR, Castro M, Sarmento SL, Moura C, Viana V, Areias JC, Areias ME. A cohort study on psychosocial adjustment and psychopathology in adolescents and young adults with congenital heart disease. BMJ Open. 2013;3(1).
95. van Rijen EH, Utens EM, Roos-Hesselink JW, Meijboom FJ, van Domburg RT, Roelandt JR, Bogers AJ, Verhulst FC. Longitudinal development of psychopathology in an adult congenital heart disease cohort. Int J Cardiol. 2005;99(2):315-23.
96. Hovels-Gurich HH, Konrad K, Skorzenski D, Minkenberg R, Herpertz-Dahlmann B, Messmer BJ, Seghaye MC. Long-term behavior and quality of life after corrective cardiac surgery in infancy for tetralogy of Fallot or ventricular septal defect. Pediatr Cardiol. 2007;28(5):346-54.
97. Shillingford AJ, Glanzman MM, Ittenbach RF, Clancy RR, Gaynor JW, Wernovsky G. Inattention, hyperactivity, and school performance in a population of school-age children with complex congenital heart disease. Pediatrics. 2008;121(4):e759-67.
98. Bellinger DC. Are children with congenital cardiac malformations at increased risk of deficits in social cognition? Cardiol Young. 2008;18(1):3-9.
99. van Rijen EH, Utens EM, Roos-Hesselink JW, Meijboom FJ, van Domburg RT, Roelandt JR, Bogers AJ, Verhulst FC. Psychosocial functioning of the adult with congenital heart disease: a 20-33 years follow-up. Eur Heart J. 2003;24(7):673-83.

100. Schaefer CJ, Hoop R, Schurch-Reith S, Stambach D, Kretschmar O, Bauersfeld U, Latal B, Landolt MA. Academic achievement and satisfaction in adolescents with CHD. Cardiol Young. 2016;26(2):257-62.
101. Nieminen H, Sairanen H, Tikanoja T, Leskinen M, Ekblad H, Galambosi P, Jokinen E. Long-term results of pediatric cardiac surgery in Finland: education, employment, marital status, and parenthood. Pediatrics. 2003;112(6 Pt 1):1345-50.
102. Bygstad E, Pedersen LC, Pedersen TA, Hjortdal VE. Tetralogy of Fallot in men: quality of life, family, education, and employment. Cardiol Young. 2012;22(4):417-23.
103. Olsen M, Hjortdal VE, Mortensen LH, Christensen TD, Sorensen HT, Pedersen L. Educational achievement among long-term survivors of congenital heart defects: a Danish population-based follow-up study. Cardiol Young. 2011;21(2):197-203.
104. Pfitzer C, Helm PC, Rosenthal LM, Walker C, Ferentzi H, Bauer UMM, Berger F, Schmitt KRL. Educational level and employment status in adults with congenital heart disease. Cardiol Young. 2018;28(1):32-8.
105. Rometsch S, Greutmann M, Latal B, Bernaschina I, Knirsch W, Schaefer C, Oxenius A, Landolt MA. Predictors of quality of life in young adults with congenital heart disease. Eur Heart J Qual Care Clin Outcomes. 2019;5(2):161-8.
106. Varni JW, Seid M, Knight TS, Uzark K, Szer IS. The PedsQL 4.0 Generic Core Scales: sensitivity, responsiveness, and impact on clinical decision-making. J Behav Med. 2002;25(2):175-93.
107. Amedro P, Dorka R, Moniotte S, Guillaumont S, Fraisse A, Kreitmann B, Borm B, Bertet H, Barrea C, Ovaert C, Sluysmans T, De La Villeon G, Vincenti M, Voisin M, Auquier P, Picot MC. Quality of Life of Children with Congenital Heart Diseases: A Multicenter Controlled Cross-Sectional Study. Pediatr Cardiol. 2015;36(8):1588-601.
108. (Destatis) SB. Schulen auf einen Blick. May 2018.
109. Forschung BfBu. Wissen über das Bildungssystem. 2019.
110. Franklin RC, Jacobs JP, Krogmann ON, Beland MJ, Aiello VD, Colan SD, Elliott MJ, William Gaynor J, Kurosawa H, Maruszewski B, Stellin G, Tchervenkov CI, Walters Iii HL, Weinberg P, Anderson RH. Nomenclature for congenital and paediatric cardiac disease: historical perspectives and The International Pediatric and Congenital Cardiac Code. Cardiol Young. 2008;18 Suppl 2:70-80.
111. Curtin R, Presser S, Singer E. The effects of response rate changes on the index of consumer sentiment. Public Opin Quart. 2000;64(4):413-28.
112. Pfitzer C, Zynda A, Hohmann C, Keil T, Borgmann-Staudt A. Educational level of childhood brain tumor survivors: results from a German survey. Klin Padiatr. 2013;225(3):138-44.
113. Zynda A, Reinmuth S, Pfitzer C, Hohmann C, Keil T, Borgmann-Staudt A. Childhood leukemia and its impact on graduation and having children: results from a national survey. Leuk Lymphoma. 2012;53(12):2419-22.
114. Visser PS, Krosnick JA, Marquette J, Curtin M. Mail surveys for election forecasting? An evaluation of the Columbus Dispatch poll. Public Opin Quart. 1996;60(2):181-227.

8. Appendix

Excerpt of Version for CHD Patient

Fragebogen: Entwicklungschancen von Kindern mit Angeborenem Herzfehler

1. Teilnehmer-Login
Um an der Umfrage teilnehmen zu können, geben Sie bitte hier Ihren neunstelligen Login-Code ein, den wir Ihnen per E-Mail zugeschickt haben:
__ __ __ __ __ __ __ __ __.

2. Wer sind Sie?
Ich bin …
□ Patient (Ich habe einen angeborenen Herzfehler).
□ Elternteil (Mein Kind hat einen angeborenen Herzfehler).
□ weder Patient noch Elternteil, sondern _____.

3. Welches Geschlecht haben Sie?
Bitte zutreffend ankreuzen.
□ männlich.
□ weiblich.

4. Wann ist Ihr Geburtstag?
Tag/Monat/Jahr
__/__/____.

5. Wurde Ihr Herzfehler schon während der Schwangerschaft diagnostiziert (pränatal)?
□ Ja, in der __ Schwangerschaftswoche.
□ Ja, aber ich weiß nicht in welcher Schwangerschaftswoche.
□ Nein, die Diagnose erfolgte erst nach der Geburt.
□ Ich weiß nicht wann die Diagnose erfolgt ist.

6. In welcher Schwangerschaftswoche erfolgte die Geburt?
□ Die Geburt erfolgte in der __ Schwangerschaftswoche.
□ Ich weiß es nicht.

7. Auf welcher Weise erfolgte die Geburt?
□ Normale Geburt/ Spontangeburt.
□ Kaiserschnitt.
□ Ich weiß es nicht.

8. Welchen Herzfehler haben Sie? Wenn Ihr Herzfehler nicht in der Liste aufgeführt ist, wählen Sie bitte die Kategorie „Einen anderen Herzfehler“ aus. Sollten Sie mehrere Herzfehler haben, wählen Sie bitte alle zutreffenden Herzfehler aus.
□ AS/AI (Aortenklappenstenose/Aortenklappeninsuffizienz).
□ ASD (Vorhofseptumdefekt).

□ AVSD (Atrioventrikulärer Septumdefekt).
□ HLHS (Hypoplastisches Linksherzsyndrom).
□ ISTA (Aortenisthmusstenose).
□ PDA (Persistierender Ductus arteriosus).
□ PS/PI (Pulmonalklappenstenose/Pulmonalklappeninsuffizienz).
□ TGA (Transposition der großen Arterien).
□ TOF (Fallot´sche Tetralogie).
□ UVH (Univentrikuläres Herz).
□ VSD (Ventrikelseptumdefekt).
□ Einen anderen Herzfehler.
□ Ich weiß es nicht.

9. Haben Sie eine weitere chronische Erkrankung, die nicht das Herz betrifft? (Mehrfachnennung möglich)
□ Ja, eine Erkrankung der Lunge.
□ Ja, eine Erkrankung des Verdauungssystems.
□ Ja, eine Erkrankung des Nervensystems.
□ Ja, eine Erkrankung des Immunsystems.
□ Ja, eine Erkrankung der Nieren.
□ Ja, eine Erkrankung der Leber.
□ Ja, eine Erkrankung folgendes Organsystems: _____.
□ Nein.
□ Ich weiß es nicht.

10. Liegt bei Ihnen ein genetisches Syndrom vor?
□ Ja, Trisomie 21.
□ Ja, CHARGE-Syndrom.
□ Ja, Di-George-Syndrom.
□ Ja, Turner Syndrom.
□ Ja, Noonan Syndrom.
□ Ja, folgendes Syndrom, nämlich: _____.
□ Nein.
□ Ich weiß es nicht.

11. Wie lange wurden Sie gestillt (inklusive späterem Zustillen bei Beikost)?
□ Ich wurde nicht gestillt.
□ Ich wurde weniger als 4 Wochen gestillt.
□ Ich wurde bis zum __ Lebensmonat gestillt.
□ Ich weiß es nicht.

12. Wie viel Zeit verbrachten Sie vor Ihrer Einschulung im Krankenhaus aufgrund Ihres Herzfehlers?
□ Weniger als 1 Monat.
□ 1 bis 3 Monate.
□ 3 bis 6 Monate.

□ 6 bis 9 Monate.
□ 9 bis 12 Monate.
□ 1 bis 2 Jahre.
□ Mehr als 2 Jahre.
□ Ich weiß es nicht.

13. Haben sich Ihre Eltern jemals bewusst gegen eine empfohlene Impfung entschieden?
□ Ja, meine Eltern haben sich bewusst gegen eine empfohlene Impfung entschieden.
□ Nein, meine Eltern haben sich nie gegen eine empfohlene Impfung entschieden.
□ Ich weiß es nicht.

14. Sind psychomotorische Störungen bzw. psychomotorische Auffälligkeiten diagnostiziert wurden, zum Beispiel im Rahmen einer U-Untersuchung?
□ Ja, eine hyperkinetische Störung/ eine Aufmerksamkeitsdefizitstörung wie z.B. ADHS.
□ Ja, eine psychomotorische Entwicklungsstörung.
□ Ja, eine Intelligenzstörung.
□ Ja, eine Störung des Sozialverhaltens.
□ Ja, eine emotionale Störung.
□ Ja, eine Depression.
□ Ja, eine Angststörung.
□ Ja, eine Lernstörung/ Lernschwäche wie z.B. eine Leseschwäche oder Rechenschwäche.
□ Ja, folgende Störung: _____.
□ Nein.
□ Ich weiß es nicht.

15. Haben Sie Geschwister?
□ Ja, ein Geschwisterkind.
□ Ja, zwei Geschwister.
□ Ja, drei Geschwister.
□ Ja, vier Geschwister.
□ Ja, fünf oder mehr Geschwister.
□ Nein.

Wenn ja: Hat eines Ihrer Geschwister auch einen angeborenen Herzfehler?
□ Ja, ein Geschwisterkind hat auch einen angeborenen Herzfehler.
□ Ja, zwei oder mehr meiner Geschwister haben einen angeborenen Herzfehler.
□ Nein.
□ Ich weiß es nicht.

16. Wurde eines Ihrer Geschwister besonders früh oder spät eingeschult?
□ Nein, ich habe ja keine Geschwister bzw. meine Geschwister sind noch nicht eingeschult.
□ Alle schon eingeschulten Geschwister wurden im Alter zwischen 6 und 7 Jahren eingeschult.
□ Ja, mindestens ein Geschwisterkind wurde mit 5 Jahren oder jünger eingeschult.
□ Ja, mindestens ein Geschwisterkind wurde mit 8 Jahren oder älter eingeschult.
□ Ja, mindestens ein Geschwisterkind wurde mit 5 Jahren oder jünger und mindestens ein Geschwisterkind mit 8 Jahren oder älter eingeschult.

□ Ich weiß es nicht.

17. Wo sind Sie überwiegend während Ihrer Schulzeit aufgewachsen?
□ Bei meinen leiblichen Eltern.
□ Bei meiner Mutter.
□ Bei meinem Vater.
□ Bei meinen Adoptiveltern.
□ Bei Verwandten.
□ In einer Pflegefamilie.
□ In einer staatlichen Institution.
□ Sonstige: _____.

18. Erhielten Sie regelmäßig eine Form von Frühförderung wie z.B. Logopädie, Physiotherapie oder Ergotherapie vor Ihrer Einschulung?
□ Ja, für weniger als 3 Monate.
□ Ja, für 3 bis 6 Monate.
□ Ja, für 6 bis 12 Monate.
□ Ja, für 1 bis 2 Jahre.
□ Ja, für über 2 Jahre.
□ Ja, aber ich weiß nicht für wie lange.
□ Nein.
□ Ich weiß es nicht.

19. Mit wie vielen Jahren erfolgte Ihre Einschulung?
□ Meine Einschulung erfolgte mit __ Jahren.
□ Ich weiß es nicht.

20. Auf welche der folgenden Schulformen erfolgte Ihre Einschulung?
□ Auf eine Grundschule.
□ Auf eine Grundschule in eine Integrationsklasse.
□ Auf eine Förderschule/ Sonderschule.
□ Auf eine alternative Schulform wie z.B. eine Waldorfschule, Montessori- Schule oder Internat.
□ Ich weiß es nicht.

21. Mit wie vielen Jahren erfolgte Ihr Wechsel auf eine weiterführende Schule?
□ Mein Wechsel auf eine weiterführende Schule erfolgte mit __ Jahren.
□ Es ist noch kein Wechsel auf eine weiterführende Schule erfolgt.
□ Ich weiß es nicht.

Wenn ja: Welche weiterführende Schulform besuchen/besuchten Sie?
□ Hauptschule.
□ Realschule.
□ Integrierte Sekundarschule.
□ Gesamtschule/ Gemeinschaftsschule.
□ Fachoberschule.

□ Gymnasium.
□ Andere: _____.
□ Ich weiß es nicht.

22. Sind/Waren Sie vom Sportunterricht befreit?
□ Ja, aufgrund einer ärztlichen Empfehlung.
□ Ja, die Teilnahme erfolgte nach meinem eigenem Ermessen.
□ Nein.

23. Mussten Sie jemals eine Klasse wiederholen?
□ Ja, ich musste die __ Klasse wiederholen.
□ Ja, aber ich weiß nicht welche Klasse ich wiederholen musste.
□ Ja, ich musste mehrere Klassen wiederholen.
□ Nein, ich musste keine Klasse wiederholen.
□ Nein, ich musste keine Klasse wiederholen, sondern habe sogar eine Klasse übersprungen.

24. Wie viel Schulzeit haben Sie aufgrund ihres Herzfehlers insgesamt verpasst?
□ Weniger als 1 Monat.
□ 1 bis 3 Monate.
□ 3 bis 6 Monate.
□ 6 bis 9 Monate.
□ 9 bis 12 Monate.
□ 1 bis 2 Jahre.
□ Mehr als 2 Jahre.
□ Ich weiß es nicht.

25. Erhalten/Erhielten Sie während der Schulzeit über mindestens 3 Monate spezielle Fördermaßnahmen?
□ Ja, Förderunterricht in der Schule.
□ Ja, außerschulischen Nachhilfeunterricht.
□ Ja, die folgenden Fördermaßnahmen _____.
□ Ja, aber ich weiß nicht genau was für einen Förderunterricht.
□ Nein, keine speziellen Fördermaßnahmen.
□ Ich weiß es nicht.

26. Mit welchem Schulabschluss haben Sie die Schule abgeschlossen?
□ Aktuell besuche ich noch die Schule.
□ Ich habe ohne einen Schulabschluss die Schule verlassen.
□ Hauptschulabschluss/ Volksschulabschluss.
□ Realschulabschluss.
□ Fachabitur/ Fachgebundene Hochschulreife.
□ Abitur/ Allgemeine Hochschulreife.
□ Einen anderen Schulabschluss, und zwar (bitte angeben):
_____.

27. Mit welchem Notendurchschnitt haben Sie das letzte Schuljahr abgeschlossen bzw. mit welchem Notendurchschnitt haben sie Ihren Schulabschluss erhalten?
□ 1 -1,9.
□ 2 -2,9.
□ 3 -3,9.
□ 4 - 4,5.
□ Unter 4,5.
□ Ich weiß es nicht.

28. Was machen/machten Sie seit/nach dem Abschluss der regulären Schule? (Mehrfachnennung möglich)
□ Aktuell besuche ich noch die Schule.
□ Ich sammele/sammelte berufliche Erfahrungen (Berufsvorbereitungsjahr, FSJ, Praktikant/-in).
□ Ich absolviere/absolvierte eine betriebliche Berufsausbildung (Lehre).
□ Ich besuche/besuchte eine Fach-, Meister-, Technikerschule, Berufs-oder Fachakademie.
□ Ich besuche/besuchte eine Fachhochschule.
□ Ich besuche/besuchte eine Universität.
□ Ich erarbeite/erarbeitete mir einen anderen beruflichen Abschluss, und zwar (bitte angeben):
_____.
□ Ich weiß es nicht

29. Welchen höchsten allgemeinbildenden Schulabschluss hat Ihr Vater?
□ Keinen Schulabschluss.
□ Hauptschulabschluss/ Volksschulabschluss.
□ Realschulabschluss/ Abschluss der polytechnischen Oberschule.
□ Fachabitur/ Fachgebundene Hochschulreife.
□ Abitur/ Allgemeine Hochschulreife.
□ Einen anderen Schulabschluss, und zwar (bitte angeben):
_____.
□ Ich weiß es nicht

Welchen höchsten allgemeinbildenden Schulabschluss hat Ihre Mutter?
□ Keinen Schulabschluss.
□ Hauptschulabschluss/ Volksschulabschluss.
□ Realschulabschluss/ Abschluss der polytechnischen Oberschule.
□ Fachabitur/ Fachgebundene Hochschulreife.
□ Abitur/ Allgemeine Hochschulreife.
□ Einen anderen Schulabschluss, und zwar (bitte angeben):
_____.
□ Ich weiß es nicht

30. Welchen höchsten beruflichen Ausbildungsabschluss hat Ihr Vater?
□ Keinen beruflichen Abschluss und ist nicht in einer beruflichen Ausbildung.
□ Noch in einer beruflichen oder universitären Ausbildung (Berufsvorbereitungsjahr, Auszubildender, Praktikant, Student).
□ Betriebliche Berufsausbildung (Lehre) abgeschlossen.
□ Ausbildung an einer Fach-, Meister-, Technikerschule, Berufs-oder Fachakademie

abgeschlossen.
□ Bachelor an einer Fachhochschule oder an einer Universität.
□ Master/Diplom an einer Fachhochschule.
□ Master/Diplom/Magister/Staatsexamen/Promotion an einer Universität.
□ Einen anderen beruflichen Abschluss, und zwar (bitte angeben):
_____.
□ Ich weiß es nicht

Welchen höchsten beruflichen Ausbildungsabschluss hat Ihre Mutter?
□ Keinen beruflichen Abschluss und ist nicht in einer beruflicher Ausbildung.
□ Noch in einer beruflichen oder universitären Ausbildung (Berufsvorbereitungsjahr, Auszubildende, Praktikantin, Studentin).
□ Betriebliche Berufsausbildung (Lehre) abgeschlossen.
□ Ausbildung an einer Fach-, Meister-, Technikerschule, Berufs- oder Fachakademie abgeschlossen.
□ Bachelor an einer Fachhochschule oder an einer Universität.
□ Master/Diplom an einer Fachhochschule.
□ Master/Diplom/Magister/Staatsexamen/Promotion an einer Universität.
□ Einen anderen beruflichen Abschluss, und zwar (bitte angeben):
_____.
□ Ich weiß es nicht

31. Welche Erwerbssituation passt zu Ihrem Vater? Bitte beachten Sie, dass unter Erwerbstätigkeit jede bezahlte bzw. mit einem Einkommen verbundene Tätigkeit verstanden wird.
□ Vollzeiterwerbstätig.
□ Teilzeiterwerbstätig.
□ Geringfügig erwerbstätig, 450-Euro-Job, Minijob.
□ Nicht erwerbstätig.
□ Ich weiß es nicht.

Wenn Ihr Vater nicht vollzeit-oder teilzeiterwerbstätig ist: Welche Bezeichnung passt zu Ihrem Vater am besten?
□ Schüler an einer allgemeinbildenden Schule.
□ Student.
□ Rentner oder Pensionär.
□ Arbeitssuchend.
□ Dauerhaft Erwerbsunfähig.
□ Hausmann.
□ Sonstige und zwar (bitte angeben):
_____.
□ Ich weiß es nicht.

Welche Erwerbssituation passt zu Ihrer Mutter? Bitte beachten Sie, dass unter Erwerbstätigkeit jede bezahlte bzw. mit einem Einkommen verbundene Tätigkeit verstanden wird.
□ Vollzeiterwerbstätig.
□ Teilzeiterwerbstätig.
□ Geringfügig erwerbstätig, 450-Euro-Job, Minijob.

□ Nicht erwerbstätig.
□ Ich weiß es nicht.

Wenn Ihre Mutter nicht vollzeit- oder teilzeiterwerbstätig ist: Welche Bezeichnung passt zu Ihrer Mutter am besten?
□ Schülerin an einer allgemeinbildenden Schule.
□ Studentin.
□ Rentnerin oder Pensionärin.
□ Arbeitssuchend.
□ Dauerhaft Erwerbsunfähig.
□ Hausfrau.
□ Sonstige und zwar (bitte angeben):
_____.
□ Ich weiß es nicht.

Eidesstattliche Versicherung

Ich, Maximilian Joseph Blickle, versichere an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorgelegte Dissertation mit dem Thema: „School Careers of Children with Congenital Heart Disease“ selbstständig und ohne nicht offengelegte Hilfe Dritter verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt habe.
Alle Stellen, die wörtlich oder dem Sinne nach auf Publikationen oder Vorträgen anderer Autoren/innen beruhen, sind als solche in korrekter Zitierung kenntlich gemacht. Die Abschnitte zu Methodik (insbesondere praktische Arbeiten, Laborbestimmungen, statistische Aufarbeitung) und Resultaten (insbesondere Abbildungen, Graphiken und Tabellen) werden von mir verantwortet.

Meine Anteile an etwaigen Publikationen zu dieser Dissertation entsprechen denen, die in der untenstehenden gemeinsamen Erklärung mit dem/der Erstbetreuer/in, angegeben sind. Für sämtliche im Rahmen der Dissertation entstandenen Publikationen wurden die Richtlinien des ICMJE (International Committee of Medical Journal Editors; www.icmje.og) zur Autorenschaft eingehalten. Ich erkläre ferner, dass mir die Satzung der Charité – Universitätsmedizin Berlin zur Sicherung Guter Wissenschaftlicher Praxis bekannt ist und ich mich zur Einhaltung dieser Satzung verpflichte.

Die Bedeutung dieser eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unwahren eidesstattlichen Versicherung (§§156, 161 des Strafgesetzbuches) sind mir bekannt und bewusst.“

Datum Unterschrift

Anteilserklärung an erfolgten Publikationen

Maximilian Joseph Blickle hatte folgenden Anteil an den folgenden Publikationen:

Publikation 1:

Promising results from a survey by the German National Register of Congenital Heart Defects.
Pfitzer, Helm, Blickle, Rosenthal, Berger, Abdul-Khaliq H, Bauer UMM, Schmitt KRL. Early Hum Dev. 2019

Beitrag im Einzelnen: Entwicklung und Gestaltung der Umfrage und Erhebung der Daten, welche die Basis dieser Arbeit bilden. Statistische Auswertung. Erstellung der Grafiken 1 bis 5. Schriftliche Mitgestaltung der Einleitung, Methodik, Resultate und Diskussion.

Teilergebnisse sind zur Publikation eingereicht worden:
Educational achievement and prenatal aspects in children after cardiac surgery due to univentricular heart physiology or transposition of the great arteries;
Constanze Pfitzer, Aleksandra Buchdunger, Paul C. Helm, Maximilian J. Blickle, Felix Berger, Ulrike M.M. Bauer, Katharina R.L. Schmitt

Beitrag im Einzelnen: Entwicklung und Gestaltung der Umfrage und Erhebung der Daten, welche die Basis dieser Arbeit bilden. Schriftliche Mitgestaltung der Einführung und der Diskussion.

_____

Unterschrift, Datum und Stempel des/der erstbetreuenden Hochschullehrers/in

Curriculum Vitae

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

Publikationsliste

Publikation 1:
Educational achievement of children with congenital heart disease: Promising results from a survey by the German National Register of Congenital Heart Defects.

Autoren: Constanze Pfitzer, Paul C. Helm, Maximilian J. Blickle, Lisa-Maria Rosenthal, Felix Berger, Hashim Abdul-Khaliq, Ulrike M. M. Bauer, Katharina R. L. Schmitt.

Early Human Development Volume 128, January 2019, Pages 27-34

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