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PO Box 117
221 00 Lund
+46 46-222 00 00

ASSISTIVE TECHNOLOGY, HUMAN RIGHTS AND POVERTY IN DEVELOPING COUNTRIES

Perspectives based on a study
in Bangladesh

Johan Borg



LUND UNIVERSITY
Faculty of Medicine

Social Medicine and Global Health
Department of Clinical Sciences, Malmö

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Abstract

Deprived of human rights, more than half of all people with disabilities in developing countries live in extreme poverty. Although considered a prerequisite for equalization of opportunities, about nine out of ten of those who need assistive technologies do not have access to them. Little is known about the socioeconomic benefits of using assistive technology in low-income countries that can inform policies and strategies. The aim of this thesis is therefore to expand the understanding of the relation of assistive technology use to human rights and poverty in these countries. This is approached theoretically and empirically. Poverty is studied in terms of deprivation of capabilities as defined by Amartya Sen.

The development of the Friction Model offers an explanation of the dynamic role of assistive technology in facilitating the enjoyment of human rights and in enhancing capabilities. A content analysis of the Convention on the Rights of Persons with Disabilities concludes that it entitles them to affordable assistive technology. Ensuring this is not only a national responsibility, but a matter of international cooperation. Data from 583 people with hearing or ambulatory impairments was collected and analyzed. The use of assistive technology was found to be predictive of enjoyment of human rights and increased capabilities, particularly among hearing aid users. User involvement in the provision of assistive technology was associated with higher outcomes.

The findings offer support for addressing human rights deprivation and poverty among people with disabilities through provision of assistive technology on theoretical, legal and empirical grounds.

Keywords: assistive technology, Convention on the Rights of Persons with Disabilities, developing countries, disability, human rights, low-income countries, poverty

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List of publications

This doctoral thesis is based on the following papers, which will be referred to by their Roman numerals:

- Paper I Borg J, Larsson S, Östergren PO, Eide AH. The Friction Model – a dynamic model of functioning, disability and contextual factors and its conceptual and practical applicability. *Disability and Rehabilitation* 2010; 32(21): 1790-7.
- Paper II Borg J, Larsson S, Östergren PO. The right to assistive technology: For whom, for what, and by whom? *Disability and Society*. (Accepted)
- Paper III Borg J, Larsson S, Östergren PO, Rahman ASMA, Bari N, Khan AHMN. Assistive technology use and human rights enjoyment: a cross-sectional study in Bangladesh. (Submitted to BioMed Central)
- Paper IV Borg J, Östergren PO, Larsson S, Rahman ASMA, Bari N, Khan AHMN. Assistive technology use is associated with reduced capability poverty: a cross-sectional study in Bangladesh. (Submitted)
- Paper V Borg J, Larsson S, Östergren PO, Rahman ASMA, Bari N, Khan AHMN. User involvement in service delivery predicts outcomes of assistive technology use: a cross-sectional study in Bangladesh. (Submitted to BioMed Central)

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*We have allowed the means by which we live
to outdistance the ends for which we live.*

Martin Luther King, Jr., Nobel Laureate

*Expansion of freedom is viewed as both the primary end
and the principal means of development.*

Amartya Sen, Nobel Memorial Laureate

People are both the means and end of development.

Mahbub ul Haq, Originator of the Human Development Index

Abbreviations

CRPD	Convention on the Rights of Persons with Disabilities
HDI	Human Development Index
GII	Gender Inequality Index
GNP	Gross National Product
ICF	International Classification of Functioning, Disability and Health
IHDI	Inequality-adjusted Human Development Index
IOI-HA	International Outcome Items for Hearing Aids
MPI	Multi-dimensional Poverty Index
PPP	Purchase Power Parity
UDHR	Universal Declaration of the Human Rights
UN	United Nations
UNDP	United Nations Development Programme
WHO	World Health Organization

Note on terminology

Taking into account the various views on terminology related to disability and international development, this thesis uses terms commonly found in texts published by the United Nations (UN) System. Therefore, ‘people with disabilities’ and ‘persons with disabilities’ are used instead of alternative terms such as ‘disabled people’ [1, 2]. The terms ‘low-’, ‘middle-’, and ‘high-income countries’ are used to indicate countries whose economies fall within corresponding Gross National Product (GNP) intervals as defined by the World Bank. Although not defined but commonly used by the UN System, ‘developing countries’ is used as an umbrella term to indicate countries with low- or middle-income economies [3, 4].

Introduction

Deprived of basic human rights, more than half of all people with disabilities in developing countries live in extreme poverty. What can be done to improve their situation?

From model, rights and user perspectives, this thesis explores one strategy to enhance living conditions that is rarely available in these countries, namely, the provision of assistive technology. To set the stage for this exploration, the frameworks and descriptions of the terms ‘disability’, ‘poverty’, ‘human rights’, and ‘assistive technology’ are outlined in this introduction. The following chapters summarize the aim, objectives, methods and results of the studies included. The last chapter discusses the findings, offers conclusions, and addresses their implications.

Disability

Disability is a multidimensional concept that is difficult to readily apply. It is not a static event but a dynamic process that can fluctuate in breadth and severity over a lifetime [5, 6].

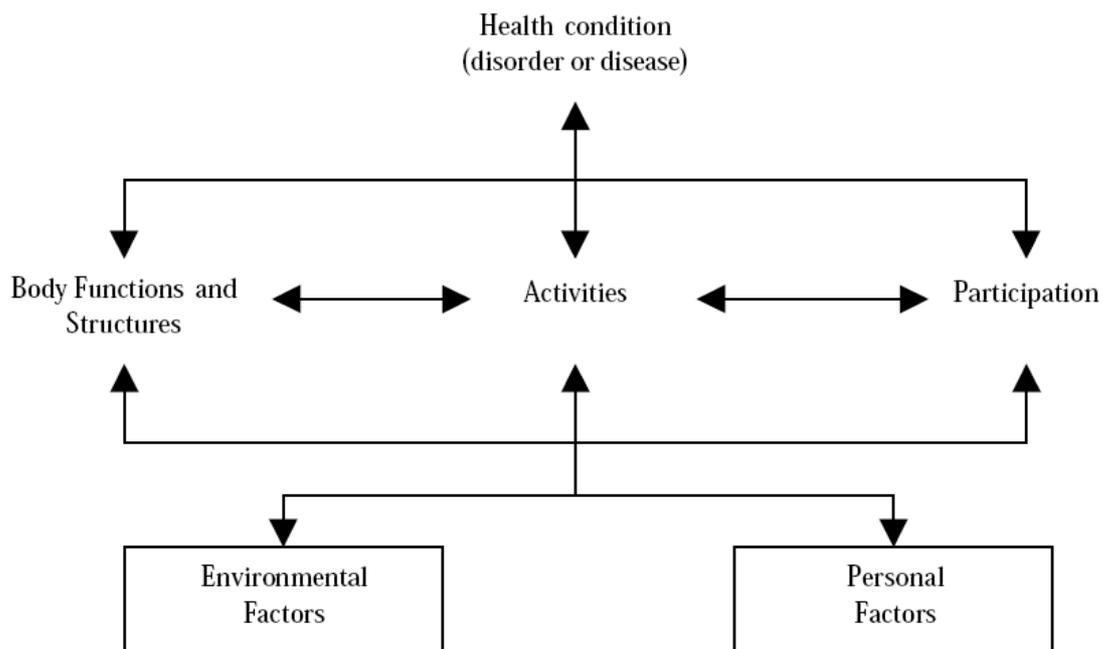
Disability definitions tend to vary and evolve to suit different purposes. Functional definitions view disability as a lack or restriction of bodily functions. They are often used in surveys and censuses to estimate service needs. According to relative definitions, disability appears in the relation between a person with impairments and an inaccessible surrounding. These definitions are intended to turn the gaze from individuals with impairments to their interaction with the surroundings. A further step is taken by the social model, where disability is seen as a property of the environment, which oppresses and acts as a barrier to people with impairments. According to administrative definitions of disability, people with disabilities are those categorized by the welfare state as being in need of or eligible for certain support. Finally, according to subjective definitions, people who perceive themselves as disabled have a disability, irrespective of the basis of such perceptions [7-12].

There have been several attempts to create a model of disability [12-14]. Two common categories of models are medical and social. Following the functional

definition of disability, medical models tend to view disability as an individual's problem performing activities as a result of an impairment. Rehabilitation aims at correcting the shortcomings of the individual. The political response is often that of modifying or reforming health care policy. On the other hand, social models view disability as a socially created problem, resulting in lack of integration of individuals with impairments into society. Rehabilitation aims at correcting the shortcomings of the environment, whether physical, social or attitudinal. Disability is not seen as an attribute of an individual, but as a political issue and a question of human rights [10, 15, 16].

Both medical and social models have been criticized for their narrow perspectives [9, 11, 15]. Therefore, when revising its medically oriented model, the United Nations (UN) System, through the World Health Organization (WHO), decided to combine the medical and social models. Through its International Classification of Functioning, Disability and Health (ICF), the WHO aims to provide a coherent view of health from biological, individual and social perspectives [16].

Figure 1. Interactions between the components of the ICF. Reproduced from [16].



The ICF consists of four components: body functions and structures, activities and participation, environmental factors, and personal factors, see figure 1. Body functions refer to the physiological and psychological functions of a person, while body structures refer to anatomical parts of a person's body such as organs, limbs and their parts. Activity is the execution of a task or action by a person, while participation is his or her involvement in a life situation. Environmental factors make up the physical, social and attitudinal environment in which a person lives

and conducts his or her life. Personal factors refer to the particular background of an individual's life and living, and are comprised of features of the individual that are not part of his or her state of health, such as, gender, race and age. These components may interact with each other and with a person's health condition. Health conditions include diseases, disorders and injuries, and are primarily classified in the International Classification of Diseases [16, 17].

In the ICF, problems in body function or structure are referred to as impairments. Difficulties in executing activities are called activity limitations. Problems a person may experience in involvement in life situations are called participation restrictions. *Disability* serves as an umbrella term for impairments, activity limitations and participation restrictions. Similarly, *functioning* is an umbrella term encompassing body functions and structures, as well as activities and participation. Disability (and functioning) is characterized as the outcome of a complex relationship between an individual's health condition, personal factors, and environmental factors, see figure 1. While maintaining that the interaction between these entities is dynamic, and that interventions in one entity may modify one or more of the others, the ICF does not model the process of functioning and disability. Rather, it intends to provide the building blocks for those who want to create models and explore this interactive and evolutionary process [16].

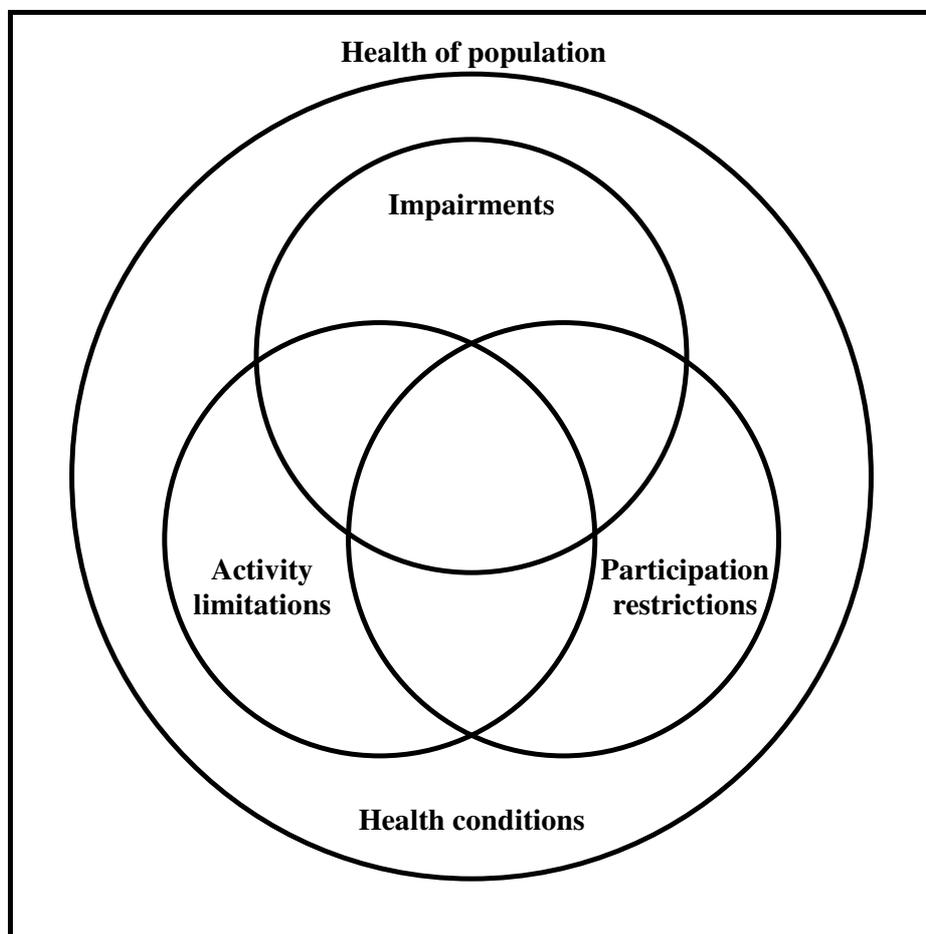
A simplified representation of disability is provided in figure 2. Impairments, activity limitations and participation restrictions overlap to a considerable degree, but they are not coextensive. Any one of them can exist in the absence of either or both of the others. An activity limitation or participation restriction can result from a health condition even when there is no impairment. Similarly, impairments can exist without activity limitations or participation restrictions, etc. [16, 18].

In the ICF, the qualifier that describes what an individual does in his or her current environment is called *performance*. The qualifier that describes an individual's ability to execute a task or an action is called *capacity*. Capacity seeks to indicate the highest probable level of functioning that a person may reach in a 'standardized' environment [16].

Although not based on the ICF, there have been attempts to model disability as a dynamic process. It has been argued that the 1997 model of the Institute of Medicine (IOM) of Washington is clearer than other models, including the ICF model, in describing disability as a dynamic process and measuring it as a relational outcome between a person and his or her environment [14]. The IOM model consists of three parts: the person, the environment and the interaction of the person with the environment. In the model, the person and the environment are depicted as a human body and a trampoline, respectively. The weight of the human body corresponds to a person's potentially disabling conditions, which includes pathologies, impairments and functional limitations. The interaction between the

person and the environment is modeled as a person standing on the trampoline. The level of disability is measured as the vertical displacement of the trampoline under the person. The displacement is a function of the strength of the physical and social environments that support an individual and the magnitude of his or her potentially disabling condition. Thus, disability is a dependent variable whose value is determined by the characteristics of the person and the environment [19]. A contribution of the IOM model is the introduction of a mechanism that describes the interaction between the person and the environment. However, the terminology and interpretation of the IOM model may carry negative connotations. Instead of measuring what a person is able to do, the model measures what a person is unable to do. Further, the model implies that potential disability is a burden.

Figure 2. A simplified model of disability according to the ICF [18].



Another document within the UN System that elaborates on disability is the Convention on the Rights of Persons with Disabilities (CRPD) [1]. Although the CRPD does not define disability, it does state in Article 1 that ‘persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their

full and effective participation in society on an equal basis with others'. Thus, interactions take place between impairments and barriers (not between person and environment) and participation is essentially hindered by impairments. This contrasts with the preamble of the CRPD, which states that 'disability results from the interaction between persons with impairments and attitudinal and environmental barriers that hinders their full and effective participation in society'. The preamble supports the notion that barriers hinder participation while Article 1 maintains the idea that impairments hinder participation. It is not surprising that some consider the disability perspective of the CRPD to be social while others maintain that it is medical [20-22]. It is beyond the scope of this thesis to further elaborate on this issue. Therefore, a pragmatic perspective can be taken by noting that the CRPD acknowledges the existence of impairments as well as barriers. This is confirmed by the fact that the diverse measures required by the CRPD are directed towards both the person and the environment. These observations indicate that the CRPD reflects disability as described by the ICF. Therefore, the framework and terminology of the ICF is applied throughout this text unless otherwise indicated.

Arriving at a global estimate of the number of people with disabilities is problematic. First, data is not available from all countries. Second, available data from different countries have rarely been collected using the same disability definitions. This is also true among those who have based their definition on the ICF, as disability is an umbrella term. In addition, the severity of a disability represents a continuum, which requires the use of agreed upon thresholds. Despite the difficulties in determining the global prevalence of disability, recent studies suggest that an estimate of 10%-12% is not unreasonable [23]. This is in relative agreement with the UN System figure of about 600-650 million people with disabilities worldwide. About 80% of them, approximately half a billion people, live in developing countries [2, 24].

Poverty

As with the understanding of disability, the perspectives on development and poverty have changed over the years. A major change occurred in 1990 when the concept of human development was introduced and presented in the Human Development Report of the United Nations Development Programme [25]. Earlier, development had mainly been perceived in economic performance and measured by per capita income. However, it was noted that countries with a high Gross National Product (GNP) per capita can have low achievements in the quality of life [26]. There are many examples of countries with a lower literacy rate, a higher infant mortality rate, or a lower life expectancy than countries with a lower per capita income. Therefore, human development has increasingly been seen as

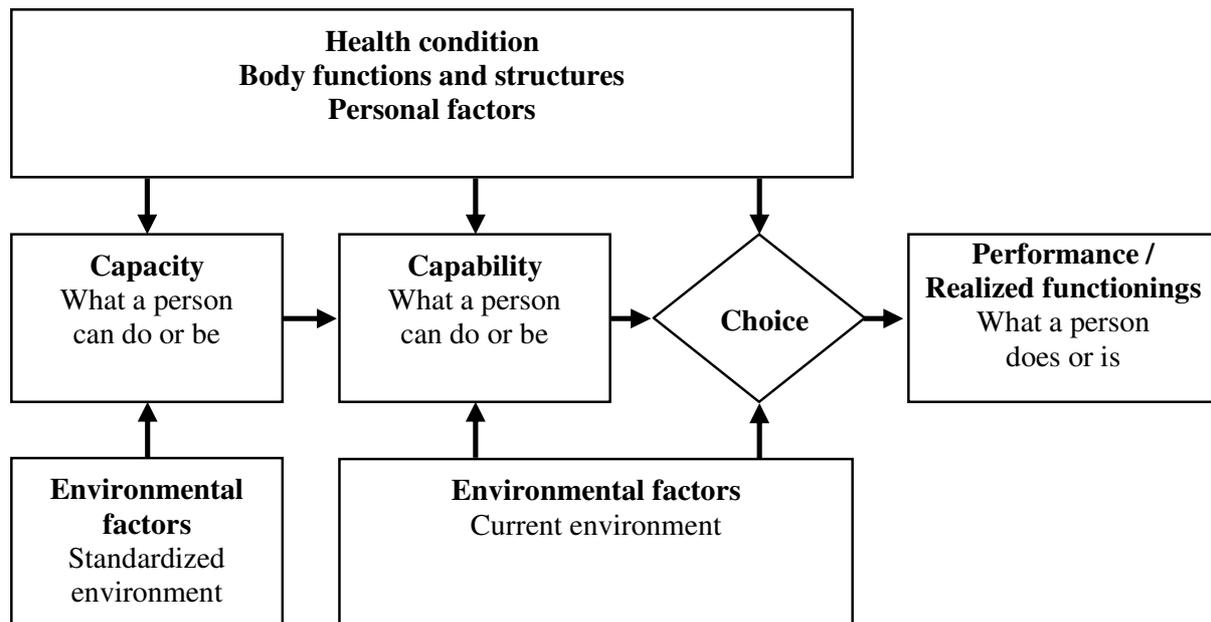
expanding not only a single freedom – income – but all human freedoms, including economic, social, cultural and political [27].

Through the capability approach, Nobel memorial laureate Amartya Sen suggests that the freedoms are evaluated in the form of individual capabilities to do things that a person has reason to value. The approach is based on the concepts ‘functionings’ and ‘capability’. Functionings are things that a person may value doing or being. They may vary from basic traits, such as being adequately nourished and free from avoidable disease, to very complex activities or personal states, such as being able to take part in the life of the community and having self-respect. Capability represents the various combinations of functionings that a person can feasibly achieve. The capability approach can seek to evaluate either things a person chooses to do, i.e., realized functionings, or things a person is substantively free to do, i.e., the capability set. Poverty is seen as deprivation of basic capabilities rather than merely low income [28].

Sen emphasizes choice and demonstrates its significance by the example of an affluent person who fasts and thereby may have the same realized functioning in terms of nourishment as a destitute person who starves. The affluent person has a different capability set as he or she can choose to eat while the destitute person is forced to starve [28].

Traditionally, poverty has been monitored by measures such as GNP per capita or Purchase Power Parity (PPP), which attempts to take into account variations in prices of goods and services in different countries. In 1990, the UNDP launched the Human Development Index (HDI) to measure human development by combining information on life expectancy, schooling and income in a simple composite measure [25]. To meet the evolving challenges in monitoring human development, three new indices were recently introduced by the UNDP. The Inequality-adjusted HDI (IHDI) takes into account inequality in the distribution of health, education and income. The Gender Inequality Index (GII) is used to measure inequalities between men and women in health, education and the labor market. Finally, the Multi-dimensional Poverty Index (MPI) identifies deprivations across the dimensions of living standards, education and health using ten indicators: nutrition, child mortality, years of schooling, school attendance, cooking fuel, drinking water, sanitation, electricity, flooring, and assets [29].

According to the originator of the HDI, Mahbub ul Haq, the human development paradigm covers all aspects of development, including economic growth. However, economic growth is only a subset of the paradigm. The basic purpose of development is to enlarge people’s choices, and the objective is to create an environment that enables people to enjoy long, healthy and creative lives [27].

Figure 3. Relationship between constructs of the capability approach and the ICF.

Disability and poverty have both been described as leading to social, economic and political exclusion [30]. Therefore, the capability approach has gained interest in the disability field, as poverty in terms of capability deprivation has some similarities with disability. It has been argued that among a number of disability models the biopsychosocial model of the ICF comes closest to understanding disability as promulgated under the capability approach [31]. In recent years scholars have explored how the capability approach can improve our understanding of disability and how it can be applied in practice [e.g., 32-36]. Drawing partly from references 31-33 a diagram that visualizes the relationship between capacity, capability, performance and realized functionings is presented in figure 3. Being a vital element of the capability approach, ‘choice’ has been included in the diagram. Influences from the individual and the environment are indicated using the ICF constructs ‘health condition’, ‘body functions and structures’, ‘personal factors’, and ‘environmental factors’.¹

About three out of five people with disabilities in developing countries live in extreme income poverty.² The situation is aggravated by the fact that the ways in

¹ For the ICF and the capability approach to match completely, either the scope of capacity and performance needs to be widened to cover both doings and beings, or the scope of doings and beings needs to be narrowed to fit capacity and performance as defined by the ICF.

² About 1.44 billion people live on less than 1.25 USD/day. People with disabilities are over-represented among the poor at a prevalence rate of 20%. Thus, about 288 million people with disabilities live in extreme income poverty, which corresponds to 55%-60% of all people with disabilities in developing countries [2,24,29,37,38].

which a person spends his or her income depend on personal and social circumstances, including disability [28]. Although households containing people with disabilities are more likely to be poor [39, 40], evaluations of poverty based on income lead to an underestimation of the needs of households having members with disabilities [28, 35, 39]. Therefore, the use of a separate poverty line for families with members with disabilities has been suggested [39]. A recent study reported that people with disabilities in two European countries needed an income level of 1.5 to 2 times higher than other people to enjoy the same level of financial satisfaction [35]. This indicates that the actual financial situation of people with disabilities and their families is likely to be worse than current statistics indicate.

The socioeconomic situation of people with disabilities in developing countries has attracted attention from the research community. Disability and poverty are associated and commonly viewed as elements of a vicious circle, where disability not only is an effect of poverty but also a cause [40-42]. In general, people with disabilities are less educated and less likely to be employed, and their households have lower standards of living than the rest of the population [39, 41, 43-52]. However, poverty is claimed to be a great equalizer, as poverty measured in terms of assets seems not to vary significantly between people with and without disabilities [51]. It has been argued that attempting to improve the quality of life of a person with disability does not only imply equalizing individual opportunities but also enhancing the life conditions of the whole family, as he or she rarely fares better than those around him or her [53].

Development and poverty can be studied from multiple perspectives. This thesis applies an individualist perspective rather than a household-centered or national perspective.

Human rights

With few exceptions, people in developing countries enjoy human rights on a much smaller scale than people living in countries with richer economies, particularly with regard to their standard of living, health, education and work [54]. Disability often enlarges this gap, causing people with disabilities to be among the most marginalized in every society, especially in low-income countries [41, 55, 56].

Human rights are those rights which are inherent to all people. There are more than 100 international human rights instruments in which they are expressed [57]. Adopted in 1948, the Universal Declaration of Human Rights (UDHR) is a foundational document of the UN human rights system. Its 30 articles include a general prohibition of discrimination as well as various types of rights and obligations. The rights include political and civil rights (e.g., the right to life,

liberty and security of person; freedom from slavery and servitude; freedom from torture and cruel, inhuman or degrading treatment or punishment; the right to recognition before the law; and freedom of thought, conscience, religion, expression, opinion, assembly and association); and also economic, social and cultural rights (e.g., the rights to social security, work, education and to a standard of living adequate for health and well-being). Although not a legally binding instrument, the UDHR has been accepted as a universal agreement on fundamental human rights norms and thereby carries significant moral weight [57].

The UDHR was followed by two covenants that further define the civil, political, economic, social and cultural rights. They create obligations on States Parties³ to establish and enact laws that promote and protect human rights at the national level [57-59]. To provide guidance on how to ensure specific rights or protect the rights of specific groups of people, seven different conventions have been adopted. These treaties also oblige States Parties to establish and enact laws at the national level. A covenant or convention comes into force once a certain number of States have ratified or acceded to it [57].

Other types of international human rights instruments adopted within the UN framework include declarations, guidelines, standard rules and recommendations. Stating general principles and practices that most States accept, these instruments have a moral force, although they are not legally binding [57].

In the ICF, enjoyment of human rights is included among activities and participation, explicitly in the chapter on community, social and civic life, and implicitly in some of the other chapters [16]. The concept of human rights also goes well with the concept of capabilities, although it is not possible to subsume one concept within the territory of the other. Many, but not all, human rights can be viewed as the rights to particular capabilities [60].

Of particular interest in the present context is the CRPD and the Standard Rules on the Equalization of Opportunities for Persons with Disabilities (Standard Rules) [1, 61].

Convention on the Rights of Persons with Disabilities

People with disabilities are routinely denied basic human rights such as education, work, freedom of movement, accessing information, proper health care, and opportunity to make their own decisions [55, 62]. In a response to this situation, the CRPD was adopted in December 2006 in order to ‘to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity’

³ States that have ratified or acceded to a treaty.

(Article 1). Considered a significant moral and practical step towards realizing the rights of people with disabilities [63], the CRPD does not recognize any new human rights, but clarifies the obligations and legal duties of States. Thus, the CRPD focuses on the actions States and other signatories must take to ensure that people with disabilities can enjoy civil, cultural, economic, political and social rights on an equal basis with others. These actions include measures related to the provision of assistive technology. The CRPD also addresses the specific rights of women and children, as well as areas in which State action is required, such as data collection, awareness raising, and international cooperation [62].

The CRPD commits to a set of general principles, including (Article 3):

- Respect for
 - inherent dignity, individual autonomy – including the freedom to make one’s own choices – and the independence of persons
 - difference and acceptance of persons with disabilities as part of human diversity and humanity
 - the evolving capacities of children with disabilities
- Non-discrimination
- Full and effective participation and inclusion in society
- Equality of opportunity and equality between men and women
- Accessibility

Concern has been expressed that the promises of the CRPD may never be realised for millions of people with disabilities, who will find themselves without attention from their governments if action stalls. For them it is therefore important that the CRPD, which entered into force in May 2008, is implemented and made to work [55, 64].

Standard Rules on the Equalization of Opportunities for Persons with Disabilities

The Standard Rules were adopted in 1993 with the intention of ensuring that people with disabilities ‘may exercise the same rights and obligations as others’, requiring States to remove barriers to equal participation. An important reference in identifying State obligations, the Standard Rules served as the basis for the national legislation of many countries. Although a special rapporteur monitors implementation on the national level, the Standard Rules are not legally binding [61, 62].

The Standard Rules set out four rules concerning the preconditions for equal participation (awareness raising, medical care, rehabilitation and support services); eight rules focusing on target areas for equal participation (accessibility,

education, employment, income maintenance and social security, family life and personal integrity, culture, recreation and sports, and religion); and ten rules dealing with implementation [61].

Rule 4, concerning support services, stipulates that governments should ensure need-based provision of appropriate assistive technology, including development, production, distribution and servicing. All people who need such technology should have access to it, including financial accessibility [61].

Assistive technology

Like ‘disability’ there are many definitions of ‘assistive technology’, each tailored to fit a specific situation. Internationally, the UN System – through the ICF – defines assistive products and technology as ‘any product, instrument, equipment or technology adapted or specially designed for improving the functioning of a person with a disability’ [16]. This definition is narrower than the one offered by the International Organization for Standardization (ISO), which says that an assistive product is ‘any product (including devices, equipment, instruments, technology and software) especially produced or generally available, for preventing, compensating, monitoring, relieving or neutralizing impairments, activity limitations and participation restrictions’ [65]. As suggested by these definitions, the range of assistive technology is wide and includes hearing aids, communication boards, wheelchairs, crutches, prostheses, orthoses, magnifiers, talking devices, and adapted eating and drinking utensils.

Technology can mean both the application of scientific knowledge for practical purposes and the machinery and equipment based on such knowledge [66]. Therefore, for the purpose of this thesis, the term ‘assistive technology’ refers to both technology and products that are adapted or specially designed for improving the functioning of a person with disability.

The ICF classifies assistive technologies among environmental factors. The wide range of assistive technologies are also classified by the ISO in its standard ISO 9999, ‘Assistive products for persons with disability – Classification and terminology’, which has been accepted by the WHO as a related member of the WHO Family of International Classifications. A conversion of the ISO 9999 classes to those of the ICF has therefore been developed [67].

According to the ICF, assistive technology is a facilitator that improves functioning, while unavailability of assistive technology is considered a hindrance caused by society [16]. From the perspective of the capability approach, assistive technology is a commodity that can be instrumental in enhancing the capability of its user [32].

Assistive technologies can be used for improving body structures and functions, as well as for improving activities and participation. Of particular interest to this thesis is the positive potential socioeconomic impact they can have. According to findings from studies in high-income countries, assistive technology can have positive effects by improving users' access to education and increasing their achievement [68, 69]. Its use is considered to be a successful strategy to help participation in work and maintenance of health [70, 71, 72].

Reports on the results of assistive technology use in low-income countries are scarce. Certain benefits in areas such as health, mobility and education have been linked to the use of assistive technology [73-75]. According to the capability approach, such effects are to be expected, as commodities – in this case assistive technology – are considered important means of facilitating capabilities. At the same time, enhanced capabilities tend to expand a person's ability to be more productive and earn a higher income, which can be particularly important to reduce income poverty [28]. Thus, the capability approach indicates that assistive technology as a commodity may contribute to enhanced capabilities and, eventually, to increased income levels [32].

Although assistive technologies have the potential to improve quality of life and participation in society, success cannot be guaranteed. Accessibility of the environment is a prerequisite for using certain types of assistive technology [76-80]. Incompatibility with the environment may cause assistive technology to be abandoned [81]. Assuming availability of assistive technologies, consumer choice is considered to contribute to the best fit possible between the user and the environment [82]. It is necessary to look beyond the technology, the environment and the physical features of the user; his or her needs, preferences and expectations must also be met [78, 83, 84].

The demand for assistive technology in developing countries is not fully known. Estimates indicate that more than 3% of a population would benefit from using hearing aids, about 1% needs wheelchairs, and about 0.5% needs prosthetic and orthotic devices. But these needs are far from being met [85-88].

Access to assistive technology is limited in many, if not all, countries [45, 89-93]. Although the CRPD and the Standard Rules require assistive technology interventions to facilitate the full enjoyment of human rights, an estimated 85%-95% of those in developing countries who need assistive technologies have no access to them [1, 2, 61, 94]. Every year less than 3% of the hearing aids needed in these countries are obtained [95].

The lack of assistive technologies is aggravated by the fact that associated services are rarely considered [96]. Findings in Africa indicate that the largest discrepancy between self-reported needs for rehabilitation services and received rehabilitation

services was for assistive technology services [97]. In general, these services include individual assessment, selection, fitting, training and follow-up to ensure safe and efficient use of the technology. The services often have a significant impact on the outcome. For example, the provision of substandard wheelchairs without clinical services, user training or the possibility of long-term local maintenance and repair has been criticized as it can result in dangerous scenarios for users [87]. Factors that limit access to assistive technology include a lack of products, skilled personnel, suitable infrastructure and financial means [98].

Aim and objectives

The overall aim of this thesis is to expand the understanding of the relation of assistive technology use to human rights and poverty among people with disabilities in low-income countries. Considering the arrival of the ICF and the CRPD and the current gap of knowledge, this issue has been addressed theoretically and empirically from model, rights and user perspectives. To achieve this aim, five studies were carried out with the following objectives:

- To develop an ICF-based model of the dynamics of functioning, disability and contextual factors, including assistive technology. (Paper I)
- To analyze the assistive technology content of the CRPD from a basic human rights perspective in order to clarify its limitations and opportunities for formulation of policy and implementation strategies. (Paper II)
- To explore the relation between assistive technology use and the enjoyment of human rights among people with disabilities in Bangladesh. (Paper III)
- To explore the relation between assistive technology use and capability poverty among people with disabilities in Bangladesh. (Paper IV)
- To explore the relation between user involvement in the delivery of assistive technology services and outcomes of assistive technology use in Bangladesh. (Paper V)

Methods

A summary of the characteristics of the five studies is given in table 1, and details of the applied methods are outlined below.

Table 1. Study characteristics.

Paper	I	II	III	IV	V
Objective	To develop a dynamic model of disability	To analyze the assistive technology content of the CRPD	To explore the relation between assistive technology use and human rights	To explore the relation between assistive technology use and capability poverty	To explore the relation between assistive technology services and outcomes
Type	Theoretical	Empirical	Empirical	Empirical	Empirical
Method	-	Content analysis	Structured interview	Structured interview	Structured interview
Materials	Literature	Literature	Interviews	Interviews	Interviews
Population	-	-	N=583	N=583	N=285

Paper I: A dynamic model of disability

In paper I, an ICF-based dynamic model of functioning, disability and contextual factors was developed after reviewing relevant literature and available models. The development process consisted of two phases: identification of model parts and design of the model.

With a focus on modeling the impact of the context and the health condition on functioning within the domains of activities and participation, using capacity and performance as qualifiers, the following six model parts were selected: capacity, performance, environmental factors, personal factors, health condition, and body functions and structures. After this a suitable physical representation was sought in the fields of physics and engineering. A mechanical, friction-based model was chosen, as it was assumed to be easy to comprehend.

Paper II: Assistive technology in the CRPD

The analysis of the assistive technology content of the CRPD in paper II was carried out by identifying types of assistive technology terms, obligations and measures related to assistive technology, target groups of the measures, areas of life targeted by the measures and actors responsible for undertaking the measures. The measures were then discussed with respect to the purpose and general principles of the CRPD.

Half of the 50 articles in the CRPD were excluded, as 21 of them concerned the introduction to and implementation of the convention, and four of them did not contain any terms related to assistive technology.

Papers III-V: Studies in Bangladesh

The relation of assistive technology use to human rights (paper III) and capability poverty (paper IV), and the relation between user involvement in service delivery and assistive technology outcomes (paper V) were explored in a structured interview study.

Context

Data was collected in Bangladesh, which has an estimated population of about 164 million living on 147 thousand square kilometers of land. According to HDI, in 2009 it ranked 146 out of 182 countries. The life expectancy at birth was 65.7 years, the adult literacy rate was 53.5% and the GDP per capita was PPP US\$ 1,241. Almost 60% of the population above 15 years of age are economically active [99]. While about 5% of the population are unemployed about 40% are underemployed, working only a few hours a week at low wages [99, 100]. Nearly 40% of the population live below the national poverty line and about 50% live on less than \$1.25 a day [100-102].

A recent study indicated a disability prevalence in Bangladesh of about 6% [103], which corresponds to nearly 10 million people. This is relatively low compared to the international estimate of 10%-12% [23]. Disability has been reported to have a devastating effect on quality of life, particularly on education and employment [104]. In 2001, Bangladesh adopted the Persons with Disability Welfare Act. This was followed by the ratification of the CRPD in 2007 and its Optional Protocol in 2008. Thus, in principle the country supports equal rights and opportunities for people with disabilities. However, for most of them these rights have not been realized, as their access to development programmes, social benefits and health and rehabilitation services is limited [105, 106]. To promote the rights of people

with disabilities, 46 focal points have been established in different ministries and departments, and a committee has been set up to monitor the implementation of the CRPD. In addition, the Disability Rights Watch Group has been formed, with representatives from civil society and the Parliamentarians' Caucus on Disability. Progress has been made in developing a new human rights-based law for people with disabilities.

WHO figures and data from other developing countries indicate that about 5 million people in Bangladesh would benefit from using a hearing aid, an estimated 1.6 million people need wheelchairs, and about 0.8 million people need orthotic devices [85, 86, 88, 107]. Less is known about the needs for other types of assistive technologies. Although there have been some government, non-governmental and private initiatives to make assistive technology available, the needs are far from being met [108, 109]. In addition to services being physically, geographically and economically inaccessible, a lack of trained personnel also accounts for this gap. This is evident in the approximately 50 orthopaedic technicians working in Bangladesh, as compared to the 5,000 trained personnel needed at different levels to conform to WHO recommendations [85].

Participants

The sample was derived from a cross-sectional survey of people with disabilities, using an interviewer-administered structured questionnaire that collected quantitative data. The inclusion criteria included having a hearing impairment with or without the use of a hearing aid or having an ambulatory impairment while using or not using a manual wheelchairs, and an age range of 15-55 years. Only users of assistive technology were included in paper V.

Due to the lack of government registers of people with disabilities in general – and users of assistive technology in particular – the non-governmental Centre for Disability in Development (CDD) was contacted in order to find eligible respondents. Through its network of over 300 partner organizations in Bangladesh, CDD has access to locally maintained registers of people with disabilities, including users of assistive technology. The way people had been included in the registers varied across and within the organizations. The primary means of identifying people with disabilities included: community meetings attended by people with disabilities, information provided by community residents, home visits based on information from local residents and authorities, people with disabilities voluntarily approaching the organizations, people with disabilities referring other people with disabilities to the organizations, and surveys. However, whether or not someone used assistive technology did not appear to affect their chances of being included in the registers.

A sample from four typical areas of Bangladesh was sought; the area in and around the capital Dhaka, the countryside, areas prone to flooding, and hilly regions. Minimizing the number of participating organizations in the selected areas in order to achieve a total of about 600 respondents, eight organizations were selected for the collection of data from people with ambulatory impairments, and ten organizations were selected as a source of data from people with hearing impairments across eight districts (Bogra, Chittagong, Dhaka, Gaibandha, Jhenaidah, Lalmonirhat, Meherpur and Savar). The sample was recruited by eight and ten interviewers, respectively. First, the interviewers selected registered users of assistive technology meeting the inclusion criteria. Second, wherever possible, the interviewers matched each user of assistive technology with the closest living registered non-user with the same type of impairment, of the same sex and of similar age (+/- 5 years). The final sample size was 583: 136 users and 149 non-users of hearing aids, and 149 users and 149 non-users of wheelchairs.

When selecting assistive technologies to be included in this study, we sought a variety based on types of impairments represented and required degrees of accessibility in the physical environment. The main reason for limiting the study to hearing aids and manual wheelchairs was that other types of assistive technology were not commonly used or available in Bangladesh. Achieving a reasonable number of respondents using other types of assistive technology to allow for meaningful comparisons was not possible due to the constraints imposed by time and budget limitations.

Data collection

The questionnaire used for collecting data was partly based on the ICF, a WHO questionnaire [110] and a questionnaire used in livelihood studies in Africa [44]. It was prepared in English and translated into Bangla. The translation was reviewed by native and non-native speakers of Bangla, including an expert on communication in simple Bangla. Under the guidance of a hired coordinator, the questionnaire was pre-tested on 30 people representing various groups of respondents. Pre-test feedback resulted in a minor revision of the questionnaire.

An instruction manual for interviewers was developed. It was based on an interviewer training manual used in a study that received the highest quality assessment score in a meta-analysis of seven HIV related studies in developing countries [111]. Ten interviewers were recruited; all worked with the rehabilitation of people with disabilities in their respective organizations. They participated in a four-day training session on interviewing and data collection techniques, including one day of practice interviewing using the questionnaire. Following input from the

training, the questionnaire was finalized. Supervised by the coordinator, the interviewers collected data between 6 November 2009 and 1 February 2010.

Interviews were conducted in the respondent's home. To protect confidentiality, family members and neighbors were requested not to be present. In interviews where the interviewer was unable to communicate with a participant, data was collected from a proxy. Chi-square tests revealed a statistically significant difference ($p < 0.05$) in proxy reporting between users and non-users of hearing aids, while there were no such difference between users and non-users of wheelchairs. Among non-users and users of hearing aids, 109 (73.2%) and 47 (34.6%) of the questionnaires, respectively, were completed with the help of proxies.

Ethical considerations

As there is no authority in Bangladesh that grants ethical approval the University of Dhaka was consulted and their ethical research praxis was followed. Potential participants were informed about the study and invited to participate. All of them consented verbally and were subsequently interviewed. Written informed consent could not be used due to the high rate of illiteracy. Respondents could refuse to answer any question or discontinue the interview at any time. No incentive for participation was offered.

Outcome variables

Paper III

Paper III studied self-reported realization of human rights. The rights to standard of living, health, education and work were included based on their fundamental importance, and rights related to receiving information and to movement were included based on their relevance for the impairments included.

Drawing from UDHR Article 25, the right to a standard of living adequate for health and well-being was measured using a composite scale consisting of four items dealing with how frequently the respondent ate three times a day until full, drank safe water and wore clothes adequate for the weather, as indicated on 4-point Likert-type scales ranging from 1=Never to 4=Always; and an item on the adequacy of the house for health, as indicated on a 3-point Likert-type scale ranging from 1=Not adequate to 3=Adequate. This standard of living scale had good internal consistency, with Cronbach alpha coefficients of 0.83 for respondents with hearing impairments and 0.81 for respondents with ambulatory impairments.

Table 2. Response alternatives and dichotomization points for outcomes in paper III.

Outcome	Hearing group	Ambulatory group
Standard of living		
High	12-15	<i>Same as hearing</i>
Low	4-11	
Necessary medical care		
Often	<i>Always or Most of the time</i>	<i>Same as hearing</i>
Seldom	<i>Seldom or Never</i>	
Physical health		
Good	<i>Good or Very good</i>	Moderate, <i>Good or Very good</i>
Poor	<i>Moderate, Bad or Very bad</i>	<i>Bad or Very bad</i>
Mental health		
Good	<i>Good or Very good</i>	Moderate, <i>Good or Very good</i>
Poor	<i>Moderate, Bad or Very bad</i>	<i>Bad or Very bad</i>
Reading ability		
Literate	Yes	<i>Same as hearing</i>
Illiterate	No	
Primary education		
Completed	Yes	<i>Same as hearing</i>
Not completed	No	
Participation in school		
High	<i>No or Mild problem</i>	No, <i>Mild or Moderate problem</i>
Low	<i>Moderate, Severe or Complete problem</i>	<i>Severe or Complete problem</i>
Work		
Working	Yes	<i>Same as hearing</i>
Not working	No	
Participation in employment		
High	<i>No, Mild or Moderate problem</i>	<i>Same as hearing</i>
Low	<i>Severe or Complete problem</i>	
Hearing performance		
Good	<i>No, Mild or Moderate problem</i>	<i>No or Mild problem</i>
Poor	<i>Severe or Complete problem</i>	<i>Moderate, Severe or Complete problem</i>
Participation in using public transportation		
High	<i>No or Mild problem</i>	<i>No, Mild or Moderate problem</i>
Low	<i>Moderate, Severe or Complete problem</i>	<i>Severe or Complete problem</i>
Ambulatory performance		
Good	<i>No or Mild problem</i>	<i>No, Mild or Moderate problem</i>
Poor	<i>Moderate, Severe or Complete problem</i>	<i>Severe or Complete problem</i>

The following outcomes were measured using dichotomous or 4- and 5-point Likert-type scales with the response alternatives given in table 2. Three items were used to measure the right to health: necessary medical care – indicating frequency of getting necessary medical care – and levels of physical and mental health. The right to education was measured using three items: reading ability (measured as

the ability to read a letter), completion of primary education (i.e. grade level 5) and level of participation in school education. The right to work was measured by the items work – indicating whether the respondent worked (including being a housewife) – and level of participation in employment. Two items were used to measure freedom of movement: participation in using public transportation and ambulatory performance. One item was used to measure freedom to receive information, namely, hearing performance. The scales for measuring participation and performance were based on the ICF.

Scale variables were dichotomized to allow for logistic regression. For six of the variables the dichotomization points were placed at different levels among the hearing and ambulatory groups in order to avoid overfitting, see table 2.

Paper IV

Although recognizing the necessity of including specific functionings in analyses, Amartya Sen has not suggested any particular set of indicators [28]. For the purpose of the study reported in paper IV, therefore, functionings that people may have reason to value were selected. Realized functionings were studied in the areas of food intake, health care, education, politics, self-determination and self-respect, while capabilities were studied in relationships. Food intake was measured by asking the respondents if they eat three times a day until full. Health care was measured by asking them if they get necessary medical care, and education was measured by completion of primary school. (It may be noted that the outcomes health care and education in paper IV are the same as necessary medical care and primary education in paper III.) Self-determination was measured by asking the respondents if they make their own important decisions about their lives. Negative views of the self among people with disabilities in neighboring India have been found to be rooted in, inter alia, negative attitudes of others [112]. Attitudes of neighbors were therefore used as an outcome proxy indicator to Sen's functioning of achieving self-respect [26], which was measured by asking the respondents how they would describe the general attitudes of their neighbors. Realization in the area of politics was measured by voted, indicating whether respondents 19 years old or older voted in the 2008 general election. The capabilities to create and maintain family relationships and to make friends and maintain friendships were measured using an ICF-based scale.

Response alternatives to dichotomous and 4- and 5-point Likert-type scales, as well as dichotomization points used to reduce the risk for overfitting, are given in table 3.

Paper V

The seven outcome variables of paper V include: use, indicating the duration of daily use of the assistive technology; improved activity, indicating how much the

assistive technology has helped; residual activity limitation, indicating how much difficulty remains; satisfaction, indicating whether the assistive technology is worth the trouble; residual participation restrictions, indicating how much hearing or moving difficulties have affected the things the user can do while using assistive technology; impact on others, indicating how much the user thinks others were bothered by his or her hearing or moving difficulties while using assistive technology; and quality of life, indicating how much the assistive technology has changed the enjoyment of life. The outcomes were measured using the 5-point Likert-type scales of the IOI-HA. Response alternatives and dichotomization points are given in table 4.

Table 3. Response alternatives and dichotomization points for outcomes in paper IV.

Outcome	Hearing and ambulatory groups
Food intake	
High	Always <i>or</i> Most of the time
Low	Seldom <i>or</i> Never
Health care	
Often	Always <i>or</i> Most of the time
Rarely	Seldom <i>or</i> Never
Primary education	
Completed	Yes
Not completed	No
Self-determination	
High	Always <i>or</i> Often
Low	Seldom <i>or</i> Never
Attitudes of neighbors	
Good	Very good <i>or</i> Good
Bad	Moderate, Bad <i>or</i> Very bad
Voted	
Yes	Yes
No	No
Family relationships	
High	No <i>or</i> Mild problem
Low	Moderate, Severe <i>or</i> Complete problem
Friendships	
High	No <i>or</i> Mild problem
Low	Moderate, Severe <i>or</i> Complete problem

Predictor variables

In papers III and IV, hearing aid use and wheelchair use (Yes or No) were used as the main predictor variables for respondents with hearing impairments and ambulatory impairments, respectively. In a complementary analysis in paper III, duration of use as dichotomized into ‘Short’ (less than 3 years) and ‘Long’ (3 years or more), was used as a predictor variable.

In order to analyze possible interaction, a dummy predictor variable was created in paper IV by coding combinations of assistive technology use and primary education.

Table 4. Response alternatives and dichotomization points of outcomes in paper V.

Outcome domains	Hearing group	Ambulatory group
Use		
Shorter daily use	None, Less than 1 hour <i>or</i> 1 to 4 hours a day	<i>Same as hearing</i>
Longer daily use	4 to 8 <i>or</i> More than 8 hours a day	
Improved activity		
Less improved activity	Helped not at all, slightly <i>or</i> moderately	<i>Same as hearing</i>
More improved activity	Helped quite a lot <i>or</i> very much	
Residual activity limitation		
More activity limitation	Very much, Quite a lot, Moderate <i>or</i> Slight difficulty	Very much, Quite a lot <i>or</i> Moderate difficulty
Less activity limitation	No difficulty	Slight <i>or</i> No difficulty
Satisfaction		
Less satisfied	Not at all, Slightly, Moderately <i>or</i> Quite a lot worth it	<i>Same as hearing</i>
More satisfied	Very much worth it	
Residual participation restrictions		
More participation restrictions	Affected very much, quite a lot, moderately <i>or</i> slightly	<i>Same as hearing</i>
Fewer participation restrictions	Affected not at all	
Impact on others		
More impact on others	Bothered very much, quite a lot, moderately <i>or</i> slightly	<i>Same as hearing</i>
Less impact on others	Bothered not at all	
Quality of life		
Less improved quality of life	Worse, No change, Slightly better <i>or</i> Quite a lot better	<i>Same as hearing</i>
More improved quality of life	Very much better	

In paper V, user involvement in the service delivery process was studied using the predictor variables preference, measurement and training.

Preference was measured by the questions:

1. Did anyone at the facility ask you what type of hearing aid/wheelchair you need or want?
2. Did anyone at the facility ask you where you want to use the hearing aid/wheelchair?
3. Did anyone at the facility ask you for what purpose you want to use the hearing aid/wheelchair?

Among hearing aid users measurement was measured by the questions:

1. Did anyone at the facility measure your hearing *before* you got the hearing aid?
2. Did anyone at the facility measure your hearing *after* you got the hearing aid?

And among wheelchair users measurement was measured by the question:

1. Did anyone at the facility take any measurements of your body before you got the wheelchair?

Training was measured by the questions:

1. Did you receive any training on how to use the hearing aid/wheelchair?
2. Did you or anyone in your family receive any training on how to maintain the hearing aid/wheelchair?

Wheelchair users were also asked:

3. Did you receive any training on how to prevent pressure sores?

Preference was recorded as 'Asked' if the respondent had answered 'yes' to at least one of the three questions; otherwise it was recorded as 'Not asked'. Measurement was recorded as 'Measured' if the respondent had answered yes to at least one of the questions; otherwise it was recorded as 'Not measured'. Training was recorded as 'Trained' if the respondent had answered yes to at least one of the questions; otherwise it was recorded as 'Not trained'.

Potential confounding variables

The outcomes of papers III-V were analyzed with respect to reported possible confounding variables, including sex, age, and place of living. To determine place of living the two categories 'village' and 'town/city' were used. The outcomes of papers III and IV were also analyzed with respect to financial situation [26, 28, 113-117]. To measure financial situation, the perception of how the respondent's household managed financially during the past year was indicated on a self-reported 4-point Likert-type scale ranging from 1=Poorly to 4=Very well.

In a complementary analysis in paper III, hearing capacity and ambulatory capacity were included as possible confounders of outcomes related to receiving information and movement. Hearing capacity and ambulatory capacity were measured as self-reported levels of difficulty in hearing or walking or moving around without assistance (i.e., without support from assistive technology, other persons, etc.). They were indicated on ICF based 5-point Likert-type scales ranging from 1=Unable to 5=No difficulty. It was hypothesized that physical accessibility to the workplace, self-rated as 'Good' or 'Poor', was associated with work-related outcomes.

As some outcomes in paper IV may relate to people who acted as proxies responding on behalf of the participants during the interview, the person reporting was included as a potential confounding variable, with the categories ‘self response’ and ‘proxy response’.

In paper V, a complementary analysis of the difference in self-reported hearing capacity and hearing performance between hearing aid users who had had their hearing measured (n=108) and those who did not (n=28) was carried out. In addition, the association between satisfaction and wheelchair users being asked all three preference questions (n=55) versus being asked none (n=59), one (n=19) or two (n=15) of the questions was investigated.

Data analyses

Questionnaire responses were recorded in a Microsoft Access database and analyzed using the statistical software Statistical Package for Social Sciences (SPSS) version 17.0. The analysis was carried out on three levels. First, descriptive statistics and t-tests, the Mann-Whitney U test, and Pearson’s chi-square test were used to report on the differences in profile characteristics between respondent groups. Second, crude odds ratios (OR) and 95% confidence intervals (CI) were calculated to explore associations between assistive technology use and the outcome variables. Third, multivariate analysis by logistic regression was performed to investigate whether the use of assistive technology or involvement in the service delivery process predicts differences in outcomes.

To avoid overfitting, i.e., having less than 10 to 15 events per predictor and confounding variables [118], adjustments were not always made for all potential confounding variables. In paper III, adjustments were therefore not made for hearing performance among respondents with ambulatory impairment. Similarly, in paper IV adjustments were not made in the analysis of participation in the 2008 election, and in paper V adjustments were not made in the analysis of impact on others.

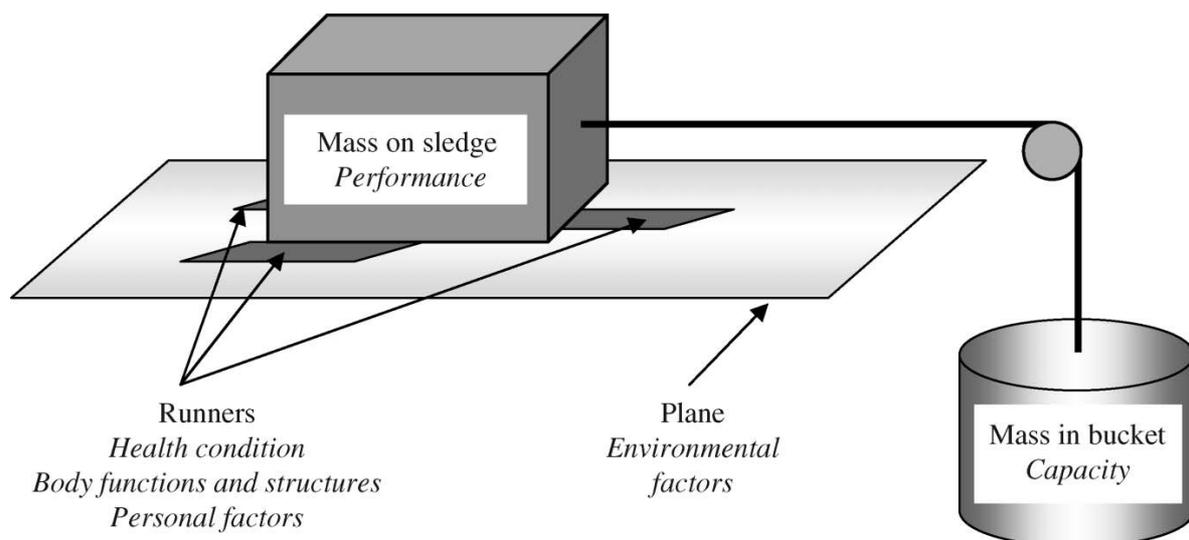
In paper III, chi-square tests were performed to assess the impact of proxies answering the questions on behalf of the respondents.

Results

Paper I: A dynamic model of disability

Based on the ICF framework, a dynamic model of functioning, disability and contextual factors was created. The so-called Friction Model incorporates capacity, performance, environmental factors, health condition, body functions and structures, and personal factors, see figure 4.

Figure 4. The Friction Model with ICF entities in *italic*. Reproduced from paper I.



The model in figure 4 consists of a horizontal plane, a weightless sledge with three runners and a weightless bucket hanging from a weightless rope attached to the sledge. The plane represents the environment and the bucket-sledge system represents the person. The mass in the bucket represents a person's capacity and gets heavier as capacity increases. The mass on the sledge represents a person's performance and gets heavier with increasing performance. The runners represent different elements or characteristics of a person that may affect his or her interaction with the environment. The sledge will move along the plane as long as the so-called friction force between the runners and the plane is overcome.

In the Friction Model, functioning is measured by how much performance can be placed on the sledge and pulled by the capacity. Consequently, disability can be measured by how much performance is left outside the sledge, i.e., how much of all ICF categories of activities and participation a person cannot perform or has difficulty performing. Disability can be seen as being caused by resistance in the interaction between a person and his or her environment.

The magnitude of the friction force depends on the sledge's load and the coefficient of friction between the surfaces in contact. For a given capacity, the performance increases when the friction is reduced. This can be achieved by changing the surface characteristics of the plane or the runners. Theoretically, in a frictionless environment the mass on the sledge can be infinite however small the mass in the bucket is. In other words, a person with no ability to execute any task or action can do whatever he or she likes in an environment free of friction.

To allow for more complex analyses, the contribution to the total frictional force from each runner can be determined. As the plane and each runner correspond to specific ICF components, the Friction Model explicitly illustrates the possibility of reducing total friction by reducing friction caused by the environment, or by reducing friction caused by one's health condition, body functions and structures, or personal factors. Performance can be affected by changes in any of these four areas.

With a given combination of health condition, body functions and structures, and personal factors, performance can be maximized by minimizing the friction caused by the environment. Thus, through friction the model links capacity, performance and environment to each other. This mechanism of friction describing the interaction between a person and the environment can be operationalized by measuring capacity and performance (for example, as suggested by the ICF). The coefficient of friction is calculated as the ratio between the capacity and performance values.

Application of the Friction Model to empirical data from Africa indicated differences in how enabling the environment was across and within countries. In one of the countries, the coefficient of friction tended to be highest for people with sensory disabilities, with no differences noted between men and women.

Paper II: Assistive technology in the CRPD

Out of 50 articles of the CRPD, 25 contain terms that encompass or may encompass assistive technology measures. General and specific assistive technology terms were found in eight of these articles. People with disabilities in general are targeted in 23 of the articles. Explicitly mentioned sub-target groups

include women; girls; children; children who are blind, deaf and deaf-blind; elderly; and personnel.

In 18 of the articles, the assistive technology actions are directly related to the issue of each article, while in the remainder of the articles the aspects of life that the actions address are not specified. The government of a signatory country is responsible for undertaking actions specified in all articles. In one article, governments of other signatory countries, international and regional organizations, and civil society, particularly organizations of people with disabilities, are included as actors.

General and specific assistive technology actions governments are required to take include:

- to undertake or promote assistive technology-related research and development
- to promote the availability and use of assistive technology
- to provide accessible information about assistive technology
- to give priority to technologies at an affordable cost
- to provide signage in Braille in buildings and other facilities open to the public
- to facilitate access to assistive technology for personal mobility and to make it available at an affordable price
- to encourage manufacturers of assistive technology to take into account all aspects of mobility for persons with disabilities
- to provide training in mobility skills to persons with disabilities and to specialist staff
- to ensure the freedom of expression and the right to access information through all forms of communication, including by accepting and facilitating the use of Braille, augmentative and alternative communication, and other preferred means of communication
- to facilitate the learning of Braille and augmentative and alternative modes, means and formats of communication
- to ensure that the education is delivered in the most appropriate modes and means of communication
- to employ qualified teachers and to train professionals and staff in the use of appropriate augmentative and alternative modes, means and formats of communication
- to promote the availability, knowledge and use of assistive technology, as it relates to habilitation and rehabilitation
- to facilitate the use of assistive technology for voting, running for election, holding office and performing public functions

Further, cooperation between and among governments and organizations is explicitly suggested in order to facilitate access to and sharing of assistive technology, and to include the transfer of technologies.

The CRPD also requires governments to undertake measures that may include elements of assistive technology. For example, they are obliged:

- to take all appropriate measures to ensure the full development, advancement and empowerment of women
- to take all necessary measures to ensure that children can enjoy rights and freedoms
- to take effective and appropriate measures to facilitate living and participating in one's community

Paper III: Assistive technology and human rights

There were statistically significant differences in the characteristics of respondents who did and did not use hearing aids while no such differences were found between users and non-users of wheelchairs, see table 6. Compared to non-users of hearing aids, users were younger, financially better off, and more frequently lived in urban areas. There were no statistically significant differences between users and non-users of hearing aids in terms of hearing or ambulatory capacity, or in the representation of men or women.

Among the hearing aid users in our study, 72 used hearing aids in both ears and 64 used a hearing aid in a single ear. Out of a total of 208 hearing aids, 105 were body-worn, 73 were placed behind the ear and 30 were placed in the ear. In the ambulatory group, 146 respondents used wheelchairs with four wheels and 3 used wheelchairs with three wheels. Seventy-four of the wheelchairs were of a non-folding design while 75 were folding. The duration of assistive technology use was on average slightly over a year higher among hearing aid users (mean 5.7 years) than among wheelchair users (mean 4.5 years), see table 6.

All crude odds ratios (COR) for the twelve human rights outcomes studied for respondents using hearing aids versus not using hearing aids were statistically significant. The crude odds ratios for higher outcomes among users of hearing aids ranged from 2.4 to 11.8 in the following areas: standard of living, medical care, physical health, mental health, reading ability, primary education, participation in school, participation in work, hearing performance, participation in using public transportation and ambulatory performance. Compared to non-users of hearing aids, users were less likely to report that they worked (COR=0.38). Among respondents with ambulatory impairments, users were statistically significantly more likely to report higher outcomes regarding medical care and ambulatory performance than non-users (COR=1.6 and COR=3.0, respectively).

Table 6. Characteristics of non-users and users of hearing aids and wheelchairs. (SD = Standard deviation. Bold = Significance level at $p < 0.05$)

Characteristics	Non-users	Users	<i>p</i> -value
Hearing group	N=149	N=136	
	<i>Mean ± SD</i>	<i>Mean ± SD</i>	
Age (years)	30.4 ± 11.6	26.5 ± 13.3	0.010
Financial situation (1-4)	1.58 ± 0.71	2.00 ± 0.91	<0.001
Hearing capacity (1-5)	1.89 ± 0.69	2.03 ± 0.68	0.078
Ambulatory capacity (1-5)	4.28 ± 1.06	4.28 ± 1.11	0.770
Duration of hearing aid use (years)	-	5.7 ± 4.2	-
	% (n)	% (n)	
Sex (Male)	55.7 (83)	62.5 (85)	0.296
Place of living (Village)	84.6 (126)	64.7 (88)	<0.001
Ambulatory group	N=149	N=149	
	<i>Mean ± SD</i>	<i>Mean ± SD</i>	
Age (years)	32.1 ± 12.4	31.8 ± 13.1	0.853
Financial situation (1-4)	1.52 ± 0.65	1.70 ± 0.78	0.057
Hearing capacity (1-5)	4.62 ± 0.91	4.64 ± 0.96	0.596
Ambulatory capacity (1-5)	2.07 ± 0.76	2.00 ± 0.71	0.501
Duration of wheelchair use (years)	-	4.5 ± 3.7	-
	% (n)	% (n)	
Sex (Male)	63.8 (95)	73.8 (110)	0.080
Place of living (Village)	79.9 (119)	71.1 (106)	0.106

After adjusting for sex, age, place of living and financial situation eleven adjusted odds ratios (AOR) of the twelve crude odds ratios for hearing aid use versus non-use remained statistically significant. While one odds ratio for wheelchair use versus non-use remained statistically significant, one was no longer statistically significant and a new odds ratio became statistically significant, see table 7. People using hearing aids were more likely to report a high standard of living to a statistically significantly degree, that is, they often receive necessary medical care, good physical health and good mental health. Although wheelchair users also tended to score higher in these categories than non-users, the differences were not statistically significant. Compared to non-users of hearing aids, users were statistically significantly more likely to report that they can read, have completed primary education and have a high participation in school. Among users and non-users of wheelchairs there were no statistically significant differences in educational outcomes. Respondents using hearing aids were statistically significantly more likely to report a high level of participation in work compared to non-users, while the difference in reported work status was not statistically significant. Compared to non-users, wheelchairs users were statistically significantly less likely to report that they worked. No statistically significant

association was found between use of a wheelchair and participation in work. Hearing aid users were statistically significantly more likely to report good hearing performance compared to non users. They were also statistically significantly more likely to report high participation in using public transportation and good ambulatory performance. There were no statistically significant differences between users and non-users of wheelchairs in terms of participation in using public transportation, while users were statistically significantly more likely to report good ambulatory performance.

Table 7. Odds ratios (95% CI) for human rights outcomes associated with assistive technology use; adjusted for sex, age, place of living and financial situation. (Bold = Significance level at $p < 0.05$)

Outcomes	High standard of living	Received necessary medical care often	Good physical health	Good mental health	Can read a letter	Completed primary education
Use of hearing aid	2.07 (1.17-3.65)	1.82 (1.00-3.32)	1.80 (1.07-3.02)	2.04 (1.19-3.50)	5.05 (2.90-8.78)	3.84 (2.19-6.71)
Use of wheelchair	1.28 (0.76-2.16)	1.33 (0.75-2.36)	1.21 (0.74-1.99)	1.23 (0.76-1.97)	1.11 (0.67-1.84)	0.88 (0.53-1.48)

Outcomes (cont.)	High participation in school	Work (including housewife)	High participation in work	Good hearing performance	High participation in using public transportation	Good ambulatory performance
Use of hearing aid	5.16 (1.57-17.0)	0.56 (0.31-1.02)	4.94 (1.31-18.6)	13.6 (7.28-25.5)	2.06 (1.23-3.44)	6.06 (2.52-14.6)
Use of wheelchair	1.18 (0.38-3.60)	0.59 (0.36-0.98)	0.65 (0.20-2.13)	-	0.85 (0.50-1.42)	3.04 (1.84-5.01)

After adjusting for age and physical accessibility to the workplace, respondents who had had a wheelchair for three years or more were more likely to report that they worked compared to those who had had a wheelchair for a shorter period of time, AOR=3.8 (1.2-12.0); and compared to non-users, wheelchair users reported a higher level of participation in work, AOR=7.7 (1.2-48.9).

Paper IV: Assistive technology and capability poverty

The characteristics of respondents in paper IV were the same as in paper III, see table 6. However, significant numbers of respondents indicated that the questions regarding participation in the 2008 election, family relationships and friendships were not applicable, see table 8.

Table 8. Number of cases with ‘not applicable’ responses by outcome in paper IV.

Outcomes	Hearing aid non-users	Hearing aid users	Wheelchair non-users	Wheelchair users
	N=149	N=136	N=149	N=149
Voted*	1	1	7	6
Family relationships	10	6	29	20
Friendships	16	16	46	36

* As the election was held on 29 December 2008 responses from those below 19 years of age at the time of the interview were not included. They constituted 22, 60, 23 and 24 of the respondents in each group in the table.

Ranging from 2.0 to 5.7, the crude odds ratios indicated that hearing aid use was associated with statistically significantly higher results regarding food intake, health care, primary education, self-determination, the attitudes of neighbors, family relationships and friendships. The crude odds ratio for ‘voted’ was not statistically significant. Compared to non-users, wheelchair users were statistically significantly more likely to report higher outcomes regarding food intake, health care and the attitudes of neighbors, with crude odds ratios ranging from 1.6 to 2.5.

Table 9. Odds ratios (95% CI) for capability outcomes associated with assistive technology use; adjusted for sex, age, place of living and financial situation. (Bold = Significance level at $p < 0.05$)

Outcomes	Food intake <i>High</i>	Health care <i>Often</i>	Primary education <i>Yes</i>	Self-determination <i>High</i>	Attitudes of neighbors <i>Good</i>	Family relationships <i>High</i>	Friendships <i>High</i>
Use of hearing aid	1.79 (0.92-3.48)	1.84 (1.00-3.38)	3.74 (2.12-6.60)	4.35 (2.16-8.76)	3.30 (1.91-5.69)	6.29 (3.34-11.9)	5.41 (2.92-10.0)
Use of wheelchair	1.35 (0.75-2.45)	1.42 (0.79-2.54)	0.91 (0.54-1.53)	0.96 (0.57-1.60)	2.63 (1.58-4.38)	1.52 (0.89-2.61)	1.11 (0.62-2.01)

Odds ratios after adjusting for sex, age, place of living, and financial situation are given in table 9. The use of a hearing aid was not statistically significantly associated with higher food intake or more frequent access to needed health care, although there was an indication that hearing aid users were more likely to report more frequent health care ($p=0.051$). Hearing aid users were statistically significantly more likely than non-users to be educated at the primary level, to be self-determined, to report positive attitudes from their neighbors, to have less problem in creating and maintaining family relationships, and to make friends and

maintain friendships. There were no statistically significant differences among respondents with ambulatory impairments except that wheelchair users were more likely than non-users to report positive attitudes from their neighbors.

For respondents with hearing impairments, odds ratios were also adjusted for sex, age, place of living, financial situation and proxy reporting, see table 10. Users of hearing aids were statistically significantly more likely than non-users to report high food intake, frequent health care, completion of primary education, good attitudes from their neighbors, less problem in family relationships, and less problem in friendships. Compared to proxy responses, self responses were statistically significantly less likely to be associated with high food intake and frequent health care, while they were statistically significantly more likely to be associated with having completed primary education, self-determination, and less problem in family relationships. No statistically significant differences in the likelihood of reporting higher outcomes regarding the attitudes of neighbors or friendships were found.

Table 10. Odds ratios (95% CI) for capability outcomes associated with assistive technology use; adjusted for sex, age, place of living, financial situation and proxy reporting. (Bold = Significance level at $p < 0.05$)

Outcomes	Food intake	Health care	Primary education	Self-determination	Attitudes of neighbors	Family relationships	Friendships
	<i>High</i>	<i>Often</i>	<i>Yes</i>	<i>High</i>	<i>Good</i>	<i>High</i>	<i>High</i>
Use of hearing aid	2.94 (1.36-6.35)	2.85 (1.40-5.80)	2.23 (1.20-4.16)	1.78 (0.78-4.06)	4.04 (2.15-7.59)	4.18 (2.12-8.27)	4.59 (2.37-8.87)
Self response	0.30 (0.15-0.63)	0.35 (0.17-0.73)	3.52 (1.87-6.62)	6.85 (3.38-13.9)	0.65 (0.34-1.22)	2.68 (1.42-5.06)	1.56 (0.80-3.03)

The crude odds ratios for combinations of assistive technology use and primary education indicated overall positive synergistic effects of hearing aid use and primary education, and rather weak evidence of synergistic effects of wheelchair use and primary education. The corresponding odds ratios, after adjusting for sex, age, place of living and financial situation, showed that the described pattern remained relatively unchanged, see table 11. In the hearing and ambulatory groups, both primary education and assistive technology use were independently associated with higher capability outcomes – hearing aid use to a greater extent than primary education, and wheelchair use to a lesser extent than primary education. In the hearing group, there were synergistic effects of hearing aid use and primary education regarding self-determination, the attitudes of neighbors, family relationships and friendships, while a synergistic effect of wheelchair use and primary education was found for self-determination only.

Table 11. Odds ratios (95% CI) for capability outcomes associated with assistive technology use and/or primary education versus no assistive technology use or primary education; adjusted for sex, age, place of living and financial situation. (Bold = Significance level at $p < 0.05$)

Outcomes	Food intake	Health care	Self-deter-	Attitudes of	Family	Friendships
	<i>High</i>	<i>Often</i>	mination <i>High</i>	neighbors <i>Good</i>	relationships <i>High</i>	<i>High</i>
No hearing aid & No primary education	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
No hearing aid & Primary education	1.54 (0.56-4.27)	0.96 (0.37-2.49)	1.46 (0.54-3.96)	1.56 (0.67-3.60)	2.98 (1.18-7.53)	1.19 (0.75-4.78)
Hearing aid & No primary education	1.74 (0.76-4.00)	1.48 (0.68-3.22)	2.39 (0.99-5.73)	2.46 (1.21-4.98)	5.57 (2.46-12.59)	3.29 (1.46-7.38)
Hearing aid & Primary education	2.25 (0.96-5.26)	2.18 (1.01-4.71)	6.42 (2.80-14.7)	6.24 (3.01-12.9)	10.9 (4.94-24.2)	10.8 (4.86-24.2)
No wheelchair & No primary education	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
No wheelchair & Primary education	1.40 (0.58-3.38)	2.29 (0.96-5.49)	2.67 (1.23-5.82)	2.47 (1.13-5.40)	2.35 (1.04-5.28)	5.31 (2.07-13.6)
Wheelchair & No primary education	1.33 (0.65-2.70)	1.83 (0.86-3.86)	0.67 (0.34-1.33)	2.85 (1.45-5.59)	1.42 (0.70-2.91)	1.44 (0.61-3.43)
Wheelchair & Primary education	1.67 (0.68-4.11)	2.00 (0.82-4.87)	4.56 (2.00-10.4)	5.46 (2.48-12.0)	3.44 (1.55-7.64)	4.69 (1.86-11.8)

Paper V: Assistive technology services and outcomes

The number and distribution of positive responses to the indicators of user involvement in the service delivery process are presented in table 12. Seventy-one percent of the hearing aid users and 60% of the wheelchair users had been asked at least one preference question. Questions about purpose seemed to be most frequent among both hearing aid and wheelchair users. Seventy-nine percent of the hearing aid users and 34% of the wheelchair users had been measured once or more. At least one type of training had been given to 53% of the hearing aid users and 41% of the wheelchair users. Among hearing aid users, training on maintenance was more common than training on use, and among wheelchair users, use training and maintenance training were equally common. Less than one out of ten wheelchair users had received training regarding prevention of pressure sores.

The mean outcome scores of hearing aid users and wheelchair users were similar except for residual activity limitations, where wheelchair users scored lower. In comparison to findings in Hong Kong, the Netherlands, Nigeria, the United States and Wales, the mean results for hearing aid users in Bangladesh were the highest among all countries for residual participation restrictions, impact on others and quality of life [119-122].

Table 12. Positive responses to questions about preferences, measurements and training.

Predictor variables	Hearing aid users		Wheelchair users	
	n	%	n	%
Asked at least one question	96	70.6	89	60.1
Asked type of assistive technology needed/wanted	69	50.7	59	39.6
Asked where assistive technology will be used	76	55.9	69	46.6
Asked purpose for using assistive technology	89	65.4	86	57.7
Measured at least once	108	79.4	50	33.6
Measured before getting assistive technology	105	77.2	50	33.6
Measured after getting assistive technology	72	52.9	-	-
Received at least one type of training	72	52.9	61	40.9
Training on use of assistive technology	53	39.0	43	28.9
Training on maintenance of assistive technology	62	45.6	43	28.9
Training on pressure sore prevention	-	-	12	8.1

Among both hearing aid users and wheelchair users, there were statistically significant positive associations between elements of user involvement in the service delivery process and less activity limitation, more satisfaction, fewer participation restrictions and greater improvement in quality of life. For hearing aid users the crude odds ratios ranged from 1.4 to 2.6, and for wheelchair users from 2.2 to 5.0. Among hearing aid users there was also a statistically significant association between involvement and improved activity (COR=1.6). The crude odds ratios for use and impact on others were not statistically significant for any of the groups.

Odds ratios modeled on composite predictor variables of preference, measurement and training were calculated after adjusting for place of living, age and/or sex, see table 13.

Hearing aid users who had been asked about their preferences were statistically significantly more likely to report less activity limitation (after adjusting for place of living, age and sex). Measuring hearing was not associated with any statistically significant difference in outcomes. Training was statistically significantly associated with improved activity among hearing aid users (after adjusting for place of living) and with fewer participation restrictions (after adjusting for place of living and age).

Wheelchair users who had been asked about their preferences were statistically significantly more likely to report less activity limitation and less satisfaction (after adjusting for place of living). Users who had been measured were statistically significantly more likely to report a higher level of satisfaction (after adjusting for place of living). Users who had received training were statistically significantly more likely to report less activity limitation (after adjusting for place of living), more satisfaction (after adjusting for place of living), fewer

participation restrictions (after adjusting for place of living, age and sex), and improvements in quality of life (after adjusting for place of living and sex).

Table 13. Odds ratios (95% CI) for IOI-HA outcomes associated with user involvement in the service delivery process; adjusted for place of living, age and/or sex. (Bold = Significance level at $p < 0.05$)

Outcomes							More improved quality of life
	Longer daily use	More improved activity	Less activity limitation	More satisfied	Fewer participation restrictions	Less impact on others	
Hearing aid users							
Asked	0.58 (0.23-1.49)	0.46 (0.17-1.24)	2.96 (1.20-7.34)	1.67 (0.69-4.05)	2.20 (0.85-5.72)	-	1.77 (0.73-4.30)
Measured	1.14 (0.42-3.11)	1.01 (0.36-2.85)	0.99 (0.37-2.66)	1.63 (0.58-4.60)	0.87 (0.30-2.50)	-	1.55 (0.56-4.34)
Trained	1.53 (0.71-3.31)	2.66 (1.20-5.91)	0.68 (0.32-1.44)	1.66 (0.79-3.50)	3.72 (1.68-8.22)	-	0.52 (0.24-1.09)
Living in village	0.36 (0.15-0.87)	0.40 (0.16-0.97)	0.39 (0.18-0.86)	1.29 (0.59-2.84)	0.35 (0.15-0.82)	-	0.68 (0.31-1.47)
Age	-	-	1.03 (0.996-1.06)	0.99 (0.96-1.02)	1.06 (1.02-1.09)	-	1.00 (0.97-1.03)
Male	-	-	1.06 (0.50-2.29)	-	-	-	-
Wheelchair users							
Asked	0.86 (0.39-1.90)	1.27 (0.52-3.07)	2.46 (1.04-5.82)	0.36 (0.13-0.99)	2.06 (0.79-5.38)	1.27 (0.54-3.02)	1.36 (0.59-3.12)
Measured	1.52 (0.67-3.47)	0.76 (0.30-1.92)	0.93 (0.36-2.37)	3.91 (1.50-10.2)	0.82 (0.31-2.18)	0.64 (0.26-1.58)	1.46 (0.64-3.32)
Trained	0.84 (0.39-1.81)	2.28 (0.94-5.57)	2.47 (1.02-5.94)	7.79 (3.00-20.2)	4.27 (1.63-11.2)	1.80 (0.77-4.25)	2.55 (1.18-5.51)
Living in village	0.60 (0.27-1.34)	0.52 (0.21-1.29)	0.27 (0.10-0.70)	0.22 (0.08-0.57)	0.092 (0.03-0.27)	-	0.66 (0.29-1.50)
Age	1.02 (0.99-1.04)	-	-	-	0.94 (0.91-0.97)	0.95 (0.92-0.98)	-
Male	1.73 (0.80-3.75)	-	-	-	8.63 (3.04-24.5)	2.46 (1.05-5.80)	0.43 (0.20-0.94)

A complementary analysis of self-reported hearing capacity and hearing performance did not reveal any significant differences between hearing aid users who had had their hearing measured and those who had not ($p=0.45$ and $p=0.37$, respectively).

After adjusting for place of living, measurement, and training, the odds ratio for reporting higher satisfaction among wheelchair users who were asked all questions versus those not asked all questions was 0.42 (0.17-1.08).

Discussion

In an attempt to expand the understanding of the relation between assistive technology use, human rights and poverty among people with disabilities in low-income countries, this thesis has approached the task from model, rights and user perspectives. The findings and limitations of the studies are discussed in the following section.

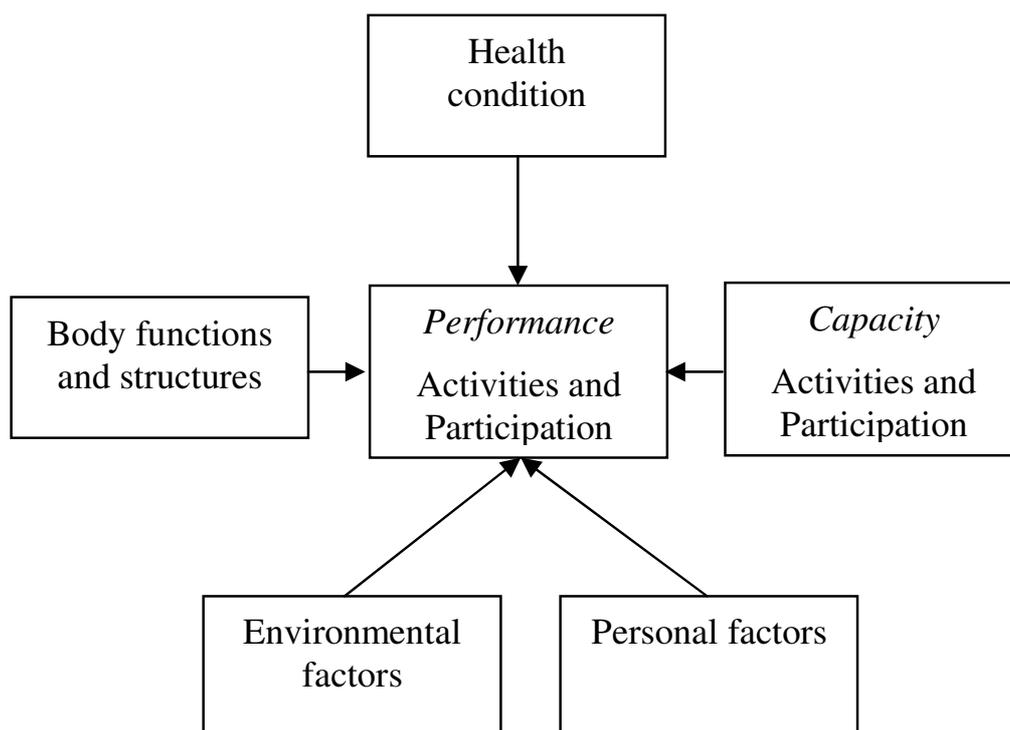
Model perspective

The ICF is a basis for understanding the process of disability and functioning at a generalized level. Knowledge of the interface and an understanding of the interaction between its building blocks may contribute to increasing the practical applicability of the ICF and to guiding interventions at various levels. This is especially important when the cost-efficiency of interventions is critical – for example, when attempting to address the large discrepancy between assistive technology services needed and those received in developing countries.

With the intention of offering a simple yet dynamic description of the complex, interactive and evolutionary process of disability and functioning, the Friction Model was developed. A model is a simplified description of a system or process to assist predictions and calculations [66]. The Friction Model reflects this limitation, since it cannot model all possible interactions within the ICF model beyond those illustrated in figure 5. According to the Friction Model, environmental factors determine performance for a given combination of health condition, body functions and structures, personal factors and capacity. Thus, changes in environmental factors, which include assistive technology, may result in changes in performance. The ICF considers assistive technology to be a facilitator, whose introduction into an environment is assumed to reduce the coefficient of friction and consequently lead to increased performance. The findings reported in papers III and IV support this. Despite similar hearing and ambulatory capacities of users and non-users of assistive technology, users reported higher performance in several areas, particularly among hearing aid users.

Like the IOM model, the Friction Model uses a physical mechanism to explain the interaction between an individual and his or her environment. This mechanism – friction – can be operationalized. A change in the coefficient of friction can be quantified by measuring the capacity and performance before and after an intervention such as the introduction of assistive technology. Thus, the model offers both conceptual and practical applicability as has been demonstrated by the examples from Africa.

Figure 5. Interactions between ICF entities in the Friction Model. Reproduced from paper I.



Through the introduction of friction, the model perspective of this thesis offers an explanation of the dynamic role assistive technology may play in facilitating the realization of human rights and in enhancing capabilities.

Rights perspective

Morally demanding and legally binding, UN conventions provide governments with guidance on how to ensure and protect human rights. Being the only convention that explicitly addresses assistive technology, the CRPD includes both limitations and opportunities to formulate assistive technology policies and implementation strategies based on such policies.

Explicit actions regarding assistive technology that must be taken to comply with the individual articles of the CRPD are not far-reaching. Despite being more recent, they fall short of the measures stipulated by the Standard Rules [61]. None of the articles of the CRPD require actions that cover all aspects of providing assistive technology. But taken all together, the actions are fairly comprehensive, although assessment and follow-up are two common elements that are not addressed [86]. It may be understood that such activities are included in so called ‘comprehensive habilitation and rehabilitation services and programmes’ [1].

In the CRPD, assistive technology is included among measures to ensure the right to freedom of expression and opinion and access to information, the right to education, and the right to participate in political and public life. It remains unclear why it is not explicitly mentioned among measures to ensure other rights, such as health and work, despite reported benefits.

As mentioned earlier, the purpose of the CRPD is to ensure the enjoyment of rights and freedoms. This may not be achieved unless assistive technology is made accessible. For example, the right to participate in cultural life may be violated when a government fails to ensure provision of a hearing aid to a person with hearing loss (adapted from [123]). Reviewing human rights in this way reveals that assistive technology can play a significant role in the full enjoyment of most, if not all, rights.

Assistive technology measures have been included in rulings to protect rights in cases brought before courts, including regional human rights courts [62]. In addition, the measures in CRPD article 20 on personal mobility and article 26 on habilitation and rehabilitation have wide applicability, which may impact the opportunities to exercise and enjoy several rights and freedoms.

In order to determine for whom and for what the CRPD requires governments to ensure the provision of applicable assistive technologies and related services, we need to take the following considerations into account:

- Assistive technologies for personal mobility should be made available at affordable cost (Article 20)
- All appropriate measures to ensure the full development, advancement and empowerment of women should be taken (Article 6)
- All necessary measures to ensure that children enjoy their rights and freedoms and to provide them with disability and age-appropriate assistance should be taken (Article 7)
- All appropriate measures to eliminate discrimination on the basis of disability should be taken (Article 4)
- Non-discrimination, equality of opportunity and equality between men and women are three principles of the CRPD (Article 3)

Based on these statements, it may be concluded that girls, boys, women and men with any kind of impairment, and in need of assistive technologies for other purposes than personal mobility, are discriminated against unless technologies that meet their needs are made available at affordable cost. As discrimination and inequality are contradictory to its general principles, it can be argued that the CRPD does provide people who experience disabilities with the right to demand affordable assistive technologies to ensure the equal enjoyment of all human rights and fundamental freedoms. This conclusion is more comprehensive than the general obligation to promote the availability and use of assistive technologies, giving priority to affordable technologies (Article 4). Thus, a non-discriminatory view of the measures in the CRPD offers legal and moral support for advocating for, formulating, implementing and evaluating policies that ensure equal access to all aspects of provision of assistive technology, irrespective of impairment, sex, age or purpose of use.

This conclusion may seem unrealistic, particularly where resources are limited. However, the obligation remains for a State Party to strive to ensure the widest possible enjoyment of the human rights, even where available resources are inadequate. It should be noted that available resources refer to resources existing within a State as well as those available from the international community through international cooperation and assistance [124]. Thus, Article 32 on international cooperation is highly relevant. Developing a system of providing assistive technologies is a matter of both national and international responsibility. Governments and organisations that have ratified the CRPD have committed to cooperation, which is explicitly suggested to include technical and economic cooperation on assistive technologies. Article 32 gives a responsibility to well-resourced countries and organizations to assist less-resourced countries in making assistive technology products and services available. The same article gives less-resourced countries an obligation towards their citizens with disabilities, and the liberty to seek such assistance from other signatories to the CRPD [98].

Unless they are interpreted and enforced by a legal framework of rules, human rights have no substance [125]. Effective development and implementation of CRPD-compliant legislation and policies requires dedication on the parts of signatories, policy- and lawmakers, implementers and representatives of the disability movement [1, 55]. Consulting the latter group is required by the CRPD and can facilitate the proper definition of rights holders [126].

As current statistics indicate, assistive technology is a missing link on the road to human rights and development for many people. Proper use of the CRPD has the potential to change this situation, particularly if the focus is on finding and implementing practical solutions [127].

User perspective

So far we have discussed the significance of assistive technology for enhancing the realization of human rights and capabilities from model and rights perspectives. It is not unexpected that they support assistive technology interventions as the development of both the ICF and the CRPD draw on experiences of people with disabilities. However, the question of whether providing assistive technology is a suitable strategy to enhance the living conditions of people in low-income countries may best be answered by empirical evidence from such settings, which leads us to discuss the findings from Bangladesh.

Assistive technology use, human rights and capability

The first two empirical studies explored the relation between assistive technology use and human rights and capability in Bangladesh. Cross-sectional data from users and non-users of hearing aids and wheelchairs in Bangladesh was analyzed using logistic regression. After adjusting for possible confounders, the findings indicate that users of assistive technology are more likely than non-users to enjoy human rights and less likely to experience capability deprivation and unrealized functionings.

Apart from insignificant differences in working status in the analysis of human rights, people using hearing aids were more likely to report positive outcomes regarding standard of living, health, education, work, receiving information and freedom of movement than people with hearing impairments who did not use hearing aids. The results support the overall positive outcomes of hearing aid use on activities and participation found in Brazil and Nigeria [119, 128]. A study in India reported that regular hearing aid use had a positive impact on the performance of students, particularly on language [74]. This may partly explain the positive relation between hearing aid use and education found here. The insignificant differences in working status between users and non-users of hearing aids are consistent with findings in Australia [129].

Hearing aid use was positively associated with freedom of movement in terms of ambulatory performance and public transportation. If this association is confirmed by further studies, the possibility of considering such devices as assistive technology for personal mobility in accordance with the CRPD may be considered. The CRPD explicitly requires governments to make such technology available at affordable prices [1].

In the capability analysis, the strongest associations were found between hearing aid use and outcomes seemingly dependent on verbal communication, such as

relationships with family and friends, making decisions, and education. Although positive, the relationships between hearing aid use and food intake and health care – functionings whose realization may be more dependent on income than communication skills – were not statistically significant.

The use of hearing aids and wheelchairs was found to be statistically significantly associated with respondents reporting better attitudes on the part of their neighbors. This finding is supported by a complementary analysis among assistive technology users only. When hearing aid and wheelchair users availed themselves of their respective assistive technology they experienced better attitudes from their neighbors compared to when they did not use assistive technology ($p < 0.001$). It is not unlikely that positive attitudes among neighbors can contribute to people achieving a higher level of self-respect, as the negative attitudes of others in a South Asian context can be a cause of negative views of the self [112]. This may have a detrimental effect on development, as negative attitudes held by people with disabilities, as well similar feelings on the part of others, can discourage them from entering the labor market [52].

Although multivariate analysis of participation in the 2008 election could not be performed, both descriptive and bivariate analyses indicate no major differences in voting between users and non-users of assistive technology.

Wheelchairs seemed to fulfill their intended purpose of providing mobility, which corresponds to reported outcomes in India and Peru [73]. On the contrary, the lack of significant differences in physical and mental health contrasts with findings from India and Peru, where nearly 50% of the respondents reported that health had improved after receiving a wheelchair [73]. Based on findings from Uganda, it has been suggested – in line with the capability approach – that assistive technology for mobility would provide opportunities for education and employment [130]. However, the findings of papers III and IV and the study in India and Peru indicate that such opportunities do not directly materialize, as no significant differences due to wheelchair use alone were found [73]. In Bangladesh, a likely reason for this may be the lack of accessible roads and school buildings [131].

The negative relation between wheelchair use and working status called for a complementary analysis, which in turn suggested that physical accessibility and duration of use may play a role. The association between physical accessibility and high participation in work must be interpreted cautiously, as the analysis was overfitted. However, the findings support current guidelines for provision of wheelchairs, where assessment of the accessibility of the proposed environmental context is recommended [86]. Assessing and ensuring physical accessibility appears a prerequisite for users to be able to benefit from a wheelchair for human rights purposes other than movement. It is uncertain if the degree of physical accessibility fully explains why wheelchair users are not more likely to report

positive outcomes than non-users, as there are more aspects of the environment which may influence participation [132, 133]. Another plausible reason could be that the nature of some of the outcomes studied did not depend heavily on mobility.

Separately, both primary education and hearing aid use significantly increased the capabilities of the participants. Further, the synergistic effects of education and hearing aid use indicate that individuals with at least primary education benefit considerably more from using assistive technology, or, in other words, hearing aid users benefit comparatively more from their education than those who do not have access to hearing aids. Such synergistic effects were not found between wheelchair use and primary education.

Although it is impossible to determine in a cross-sectional study, the question of causality between the predictors and outcomes studied is of great interest. For most outcomes this will remain a question, but for some it can be argued that the findings support a causal chain. First, the use of assistive technology may have a positive effect on the perceived attitudes of one's neighbors. This is supported both by the comparison of users and non-users of assistive technology in paper IV, as well as the comparison of users availing and not availing themselves of their assistive technologies, which was mentioned earlier. Second, considering that there were no statistically significant differences in hearing or ambulatory capacities between users and non-users of assistive technology, and assuming that their environments were relatively similar except for the presence of assistive technology, it seems not unlikely that the reported higher levels of hearing and ambulatory performance are effects of assistive technology use. However, before such claims are scientifically made, appropriately designed studies must be undertaken.

Disability and poverty are commonly viewed as elements of a vicious circle, where poverty may lead to disability and disability may lead to poverty [30, 41, 56]. As mentioned in the introduction, the capability approach offers the mirror opposite view – a virtuous circle – where enhanced capabilities may lead to reduced income poverty, which in turn may result in further enhanced capabilities [28]. Considering the findings, it is not unlikely that assistive technology can contribute to breaking disability–poverty cycles and transforming them into virtuous capability–poverty reduction cycles.

Service provision and assistive technology outcomes

In order to find guidance for appropriate systems of providing assistive technology in developing countries, the relation between user involvement in the delivery of services and the effects of assistive technology use was studied. Users of hearing

aids and manual wheelchairs in Bangladesh report outcomes as measured by the IOI-HA at internationally comparable levels. The analyses indicate statistically significant associations between the effects of using hearing aids and wheelchairs and the way these products were provided. The positive relation between training and outcomes confirm similar findings in previous studies [134].

Due to the temporal order of service delivery, assistive technology use and the outcome measurements, it may be argued that user involvement in the delivery of services improves the outcomes. Although a causal relationship may only be determined by a randomized controlled trial, the findings of this study offer empirical support for a user-centered delivery of assistive technology services. This accords with the notion in the CRPD of an individual's freedom to make his or her choices [1], which is to be respected in the provision of assistive technology as well [135].

Participants using hearing aids were comparatively more involved in the process than were wheelchair users, especially regarding measurement. One out of five hearing aid users had not had their hearing tested while two out of three wheelchair users had not had their body measurements taken.

Asking hearing aid users about their preferences and providing them with training regarding the use or maintenance of their products is indicative of improved activity, less activity limitation and fewer participation restrictions. Thus, user preferences and training need to be considered in the delivery of hearing aid services.

Participants who had their hearing tested during the assessment process, whether before and/or after fitting of the hearing aid, did not report better outcomes than those who did not have their hearing tested. One reason for this may be that the hearing measurement was not carried out satisfactorily or did not have an effect on the selection and setting up of the hearing aid. Another reason may be that the hearing tests provided no additional benefits for the majority of the participants, which the result of the analysis of hearing capacity and performance indicate. As the mean outcome scores were relatively high from an international point of view, this result could indicate that all potential users of hearing aids may not need to have their hearing measured to benefit from using hearing aids. A delivery strategy based on such an assumption could potentially reduce the cost of providing hearing aids in less-resourced settings and make them more widely available. The idea of having someone minimally trained to fit hearing aids without availability of follow-up services is not new, but has earlier been rejected on ethical grounds [88]. However, if future studies confirm the findings reported here, such a position may need to be reconsidered in order to increase access to hearing aids through simple, low-cost service delivery strategies. Such a step could be crucial, as currently only 3% of the annual need for hearing aids is reportedly met [95].

Hearing aid users living in villages were less likely to report better outcomes. The reason for this is not known, but it may be that full participation in a town or city setting requires better hearing than in a village, and thus the benefits of using a hearing aid in a town or city are even more appreciated.

The findings support the current WHO recommendations for user involvement in the provision of manual wheelchairs [86]. Using an adapted version of the IOI-HA to score outcomes of wheelchair use was a new approach. The outcomes were similar to those reported by hearing aid users across six of the seven domains. The higher level of residual activity limitations reported by hearing aid users may be explained by their physical environment being less accessible to wheelchairs, which is indicated by the adjusted odds ratios for wheelchair users living in villages, compared to those living in towns or cities.

There is evidence for the importance of taking measurements of the wheelchair user and, particularly, providing training in use, maintenance and pressure sore prevention in order to achieve better results. Also, asking for a user's preferences is associated with less activity limitation. On the other hand, asking about preferences is indicative of lesser satisfaction. The reason for this could not be further investigated within the study, but a possible explanation might be that questions about preferences created expectations or gave rise to requirements that were not possible to meet with available wheelchair models.

Limitations

The studies included in this thesis carry certain limitations, which should be taken into consideration when interpreting the findings.

The use of the Friction Model presented in paper I, a simplification of the ICF model of disability and functioning, is limited to the study of how performance is affected by individual and environmental factors. Variations in friction coefficients at disaggregate levels may not be discernable at aggregate levels, and the coefficient of friction may not be linear in a given environment. Issues such as these may limit the practical applicability of the Friction Model, although its conceptual applicability remains.

A limitation in the assistive technology content analysis of the CRPD reported in paper II was the lack of guidance in the form of previous content analyses of UN conventions, as no such studies were found. The method was chosen because it is a rather straightforward way to analyse how different themes are reflected in a text. It offers transparency and can be easily replicated. As interpretation may reduce the objectivity and cast doubts about the validity of the results, variables requiring a minimum of interpretation were selected [136].

The studies reported in papers III to V suffer from the inherent limitation of cross-sectional designs in exploring causal relationships. Although there was a temporal difference between delivery of assistive technology services and the collection of data in paper V, longitudinal studies are needed to assess the causality.

Like most countries, Bangladesh does not maintain a national register of users of assistive technology, and since the prevalence of assistive technology use is very low, it was impossible to achieve a representative sample within the resource constraints of this research. The difficulty of obtaining representative samples in low-income countries is well-known, particularly when hidden and vulnerable populations are involved [137, 138].

Compared to other categories relatively large amounts of data were missing for family relationships and friendships in paper IV, particularly among people with ambulatory impairments, which may introduce bias. The characteristics of respondents missing for these categories were therefore analyzed. Comparisons between respondents with similar sex, age, place of living and financial situations who used and did not use assistive technology indicated that the strength of the associations would likely not be reduced if the missing respondents would have responded similarly to those with the same characteristics.

As the sample in this study was not randomly selected there is a risk of selection bias. It should be noted, however, that in every sampling area all registered and eligible users of hearing aids and wheelchairs were included. As there were more non-users of assistive technology in the areas, each user of assistive technology was matched with a non-user as far as circumstances allowed. Besides this, there was no obvious difference in the chance of being selected due to one's use of assistive technology or not. There were no statistically significant differences of key characteristics between users and non-users of wheelchairs, while such differences occurred between users and non-users of hearing aids in terms of age, place of living and financial situation.

If the capacity of non-users of assistive technology were to exceed the capacity of users, it is likely that any differences in outcomes would have been underestimated since assistive technology benefits its user. On the contrary, if the capacity of users had exceeded the capacity of non-users, it is likely that any differences in outcomes would have been overestimated. Although no statistically significant differences in self-reported capacities between users and non-users of assistive technology were found, the lack of objective assessment of the respondents' capacities is a limitation of the study.

In paper III, the existing variations between self- and proxy-reported data among respondents with hearing impairments seem logical, i.e. that the reason for a proxy answering may be that the respondent's hearing performance is poor, a

circumstance often associated with a lower level of education and consequently, the inability to read.

It is possible that the respondents in paper V did not correctly recall what questions they had been asked or what training they had received as part of the service delivery. In an attempt to minimize the chance of reporting that no questions had been asked or no training had been provided when, in fact, such questions had been asked and training provided, composite predictor variables were used. From collected data, it was not possible to know how the training had been provided. Such issues need to be addressed in future research in order to expand our understanding of how intervention-related factors influence the use of assistive technology [134].

Employing an administered questionnaire can result in systematically biased answers, as responses may be given to satisfy the interviewer; but as data was provided by respondents within the same cultural context, such bias may not significantly affect the conclusions. Relying on self- and proxy-reported data results in lack of knowledge about how closely the responses correlate with objective measures. Also, the understanding of Likert-type scales may vary, which may influence individual responses.

Evidence of the validity of using perceived attitudes of neighbors as a proxy to indicate self-respect in a South-Asian context has not been found. Although it is generally agreed that the way one thinks and feels about oneself often depends on the attitudes of others, it has been argued that self-respect does not necessarily presuppose having received respectful treatment from others [139]. This idea finds support in an Indian study of self-concept among people with disabilities. It reported that positive views of the self were largely a consequence of internal factors, while negative views were rooted in such external factors as poverty and attitudes of others [112]. Thus, as several elements are involved, any conclusions based on findings about the attitudes of neighbors and achievement of self-respect need to be drawn cautiously.

For the purpose of simplicity in presenting the logistic regression models, and given the limitations of the sample size, adjustments were made for more or less the same confounders for all outcome categories. This resulted in the inclusion of confounders whose correlation with some outcomes had not necessarily been previously reported and the exclusion of known confounders. This could potentially affect the findings. However, preliminary adjustments of the reported confounders only marginally affected the results. As all dichotomization points were not the same for the hearing and ambulatory groups, it was not possible to compare these groups across all outcome categories.

Standard of living may determine one's quality of health, and education may determine both health and standard of living. However, they were not included as possible confounders in paper III because they were included among the outcome variables. Also, self-reported financial situation of the household was included as a possible confounder, rather than personal or household income. The main reason for this was that the use individuals can make of incomes varies [28], and that the subjective perspective of how well a household copes financially was expected to include this variation – at least to some extent.

To avoid overadjustment, no potential confounders considered being on causal paths between predictors and outcomes were included, with one possible exception: the use of proxy reporting as a potential confounding variable in paper IV. It is plausible that the use of hearing aids enables self-reported responses, which was predictive of a high level of self-determination, see tables 9 and 10. This possibility needs to be considered when interpreting the findings.

To reduce the risk of overfitting, dichotomization points were selected to maximize the number of events in the smallest group. Despite this, the models were deliberately overfitted in a few analyses, which has been indicated. Great care should be exercised when interpreting these results.

The close link between human rights and capabilities was reflected in papers III and IV by the use of the same outcome measures for medical care and education. Using the capability approach to explore the associations between assistive technology use and poverty is novel, which prevents the possibility of discussing the findings in light of similar research. Changes in calculated odds ratios after adjusting for sex, age, place of living and financial situation support the capability approach's notion that characteristics of the individual and the environment do have an effect on capability, and consequently on realized functionings [26, 28].

Amartya Sen's functionings contain similarities with the activities and participation of the ICF, as well as with certain human rights. To allow for comparisons between future studies, it would be necessary to agree on which functionings should be included and how to measure them.

Conclusions

This thesis offers theoretical, jurisprudential and empirical support for addressing human rights deprivation and capability poverty among people with disabilities in low-income countries through the user-involved provision of assistive technology.

The main conclusions that can be drawn from the model, rights and user perspectives are:

- Suggesting a conceptual yet operationalizable understanding of the mechanism between capacity and performance, or of the interaction between an individual and the environment, the Friction Model offers a theoretical explanation of the dynamic role of assistive technology in facilitating the realization of human rights and in enhancing capabilities.
- Nationally and internationally, governments have moral and legal responsibilities to ensure that assistive technologies are provided to those who need them. The CRPD entitles all people with disabilities to the right to demand available and affordable assistive technology as a means to ensure their full and equal enjoyment of all human rights and fundamental freedoms.
- Use of assistive technology was predictive of the realization of human rights and capability in Bangladesh, particularly among users of hearing aids.
- User involvement in the delivery of assistive technology services was predictive of positive outcomes of assistive technology use in Bangladesh. The lack of association between hearing measurement and outcomes calls for further investigation.
- Research is required to determine the temporal relation, if any, between assistive technology use and human rights and capability outcomes. Studies are also needed to understand what factors affect the relation between work and assistive technology use.

Implications

The main implications are:

- The findings offer support for addressing human rights deprivation and capability poverty among people with disabilities in developing countries through the user-involved provision of assistive technology. This is not only a national responsibility, but a matter of international cooperation.
- The Friction Model can help shift the focus from a static medical or social perspective to a dynamic understanding of how to overcome barriers on different contextual levels through technical innovations, socioeconomic reforms and rights.
- Resources need to be made available for longitudinal studies of the outcomes of assistive technology use and to develop cost-effective strategies for providing assistive technology, particularly in low-income countries.

Sammanfattning

Avhandlingen ger teoretiskt, juridiskt och empiriskt stöd för att genom hjälpmedelsförsörjning öka möjligheterna för människor med funktionshinder i låginkomstländer att förverkliga sina mänskliga rättigheter och minska sin fattigdom.

Människor med funktionshinder är överrepresenterade bland världens fattiga. I utvecklingsländer lever mer än hälften av dem i extrem fattigdom med en begränsad möjlighet att åtnjuta mänskliga rättigheter. Bland de som behöver tekniska hjälpmedel saknar ungefär nio av tio sådana, trots att hjälpmedel under lång tid ansetts vara en förutsättning för delaktighet och jämlikhet. Kunskapen om nyttan med hjälpmedel i dessa länder är begränsad. Denna är betydelsefull för att utforma effektiva riktlinjer och strategier för hjälpmedelsförsörjning. Syftet med denna avhandling är därför att bidra till en ökad förståelse av sambanden mellan hjälpmedelsanvändning, fattigdom och åtnjutandet av mänskliga rättigheter i låginkomstländer. Dessa har undersökts teoretiskt och empiriskt. Fattigdom har inte studerats i ekonomiska termer utan i relation till Amartya Sens definition av nedsatt förmåga, det vill säga en begränsning i att göra eller vara det man kan ha anledning att värdesätta.

En så kallad friktionsmodell har utvecklats. Denna erbjuder en förklaring av den dynamiska roll tekniska hjälpmedel spelar för att underlätta förverkligandet av mänskliga rättigheter och öka individens förmåga. Det som skrivs om hjälpmedel i Förenta nationernas konvention om rättigheter för personer med funktionsnedsättning har analyserats ur ett icke-diskriminerande perspektiv. Enligt denna ges alla berörda rätt till ekonomiskt överkomliga hjälpmedel. Att tillförsäkra denna rätt är både ett nationellt och ett internationellt ansvar. Data från en enkätundersökning i Bangladesh bland 583 personer med nedsatt hörsel eller gångförmåga i åldrarna 15 till 55 år har insamlats och analyserats. Det visade sig bland annat att de som använde hörapparat eller rullstol i större utsträckning upplevde att de åtnjöt mänskliga rättigheter och rapporterade högre förmåga än de som inte använde hjälpmedel. Det framkom också att de personer som aktivt deltog i hjälpmedelsförsörjningsprocessen hade större nytta av sina hjälpmedel än andra.

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